TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

OFFICE OF PLANNING

September 1965

TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

U.S. DEPARTMENT OF COMMERCE
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PREFACE	September 1965

The agencies concerned with making decisions on when and where to construct new urban transportation facilities, or to improve existing ones, must consider many factors in reaching sound decisions. Consequently, considerable time, money, and effort are usually expended in the planning and design of such improvements. For the most part, the planning work is carried on within the framework of an urban transportation study.

Since the end of World War II, a number of urban transportation studies have been conducted in an increasingly comprehensive manner. Significant improvements in both basic study philosophy and analytical methodology have greatly contributed to a better understanding of the urban transportation problem.

This understanding has resulted in a concerted effort toward the development of a transportation planning process which utilizes the interrelationships between available transportation facilities, land use, and socio-economic characteristics of the population to provide quantitative information on the travel demands created by alternate land use patterns and transportation systems in an urban area. Such information can then be used by various agencies to make decisions about when and where improvements should be made in transportation networks to satisfy the present and future travel demands and to promote desirable land development patterns.

The technical considerations of an urban transportation study generally involve four integrated phases; (1) data collection; (2) data analysis and estimating; (3) policy decision making; and (4) plan implementation. The integration of the four phases is achieved by designing the data-gathering phase to obtain the facts necessary for developing estimating procedures for making estimates. These estimating procedures must provide quantitative information about the probable consequences of decisions concerning alternate urban development and transportation plans. Decisions based upon a knowledge of the alternate plans will in turn permit the development of programs for plan implementation.

Briefly, the four phases accomplish the following:

- The data collection phase consists of the origin-destination survey and its associated inventories.
- The data analysis and estimating phase, using the data collected in the first phase, undertakes the population analysis, economic analysis, land use analysis, trip generation estimates, trip distribution estimates, and traffic assignments.

- The traffic assignments are used to provide information on the capabilities of the various alternate transportation systems.

- The plan implementation phase develops from the decision making phase as a set of construction priorities based on criteria which include such factors as community interest, availability of funds, limitations on revenue, present programs and the public works plans of other jurisdictions.

This manual covers the details and mechanics of computer application for traffic assignment and trip distribution. The remainder of this preface describes the contents of this manual in greater and more technical detail.

Traffic assignment and trip distribution are two key phases of the transportation planning process. These phases generate the quantitative data on travel needed to properly plan transportation facilities.

The traffic assignment techniques provide an estimate of the probable traffic on each segment of a transportation network. The alternate methods of assignment to be covered in this volume are the all-or-nothing and diversion methods. The history and theory of traffic assignment are covered in detail in a previous publication by the Bureau of Public Roads(1)1/. Trip distribution techniques provide for distributing the trips emanating from each zone in the study area to other zones. This manual covers the necessary phases for trip distribution with the gravity model formula or the Fratar formula. The history and theory of the gravity model are covered in reference (2).

The system described in this volume is designed to process a basic set of trip data cards. It allows the computation of surveyed trip length frequency, distribution of trips between zones by the gravity model formula, and assignment of trip interchanges to an existing transportation network. The gravity model program automatically adjusts zonal attractions for a given set of traveltime factors and computes the new trip length frequency from which traveltime factors can be adjusted.

The system also accommodates estimates of future trip production and trip attraction values for use in a gravity model trip distribution, and then goes on to assign the trip distribution to a future transportation network.

The analytical procedures described in this volume are mechanized by a highly flexible series of computer programs which utilize the IBM 1620 (60K) electronic computer, coupled with the capabilities of IBM electronic accounting machines.

This battery of computer programs was developed by several State highway departments and the Bureau of Public Roads, and is generally applicable to urban areas with populations up to 150,000 persons. In order to utilize the computer programs for this system, the study area must be described by a maximum of 699 nodes, of which 200 may be zone centroids. The maximum traveltime that can be accommodated is 99 minutes.

1/ The numbers in parentheses identify references in appendix A.

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CHAPTER I - INTRODUCTION	September 1965

A. The Process

It is now widely recognized that urban travel patterns are a function of:

1. The type and extent of transportation facilities in an area;

2. The pattern of activities in an area, including the location and intensity of land use; and

3. The social and economic characteristics of the population of an urban area.

The recognition of these facts has resulted in the development of a travel forecasting process which utilizes the above relationships to provide information on the travel demands created by the distribution of activities and the transportation system.

The technical considerations of the urban travel forecasting process involve four integrated steps: (1) the inventories; (2) the analysis of existing conditions and calibration of forecasting techniques; (3) the forecast; and (4) systems analysis. The complete process is shown in figure I-1; the cross-hatched areas of the diagram will be discussed in this manual. In order to present their proper positions in the urban travel forecasting process, different phases of this process will be discussed in turn, with the traffic assignment and trip distribution phases being treated in more detail. A brief discussion of trip generation is provided in chapter VIII. Before getting into the details of each phase, some general statements are in order. A statement about traffic assignment follows in section B. and a statement about trip distribution is in section C.

B. Traffic Assignment

The traffic assignment phase refers to the estimation of the number of vehicles that will use each individual section of the transportation system. The estimation of the load on various sections or links may be for present conditions or any future year. For future year assignments, a travel forecast must first be made in order to obtain the volumes. After forecasts of the future travel have been made, the volumes are assigned to a transportation network. The results are evaluated in accordance with the desired level of service and the social and economic consequences of the system. The

URBAN TRAVEL FORECASTING PROCESS

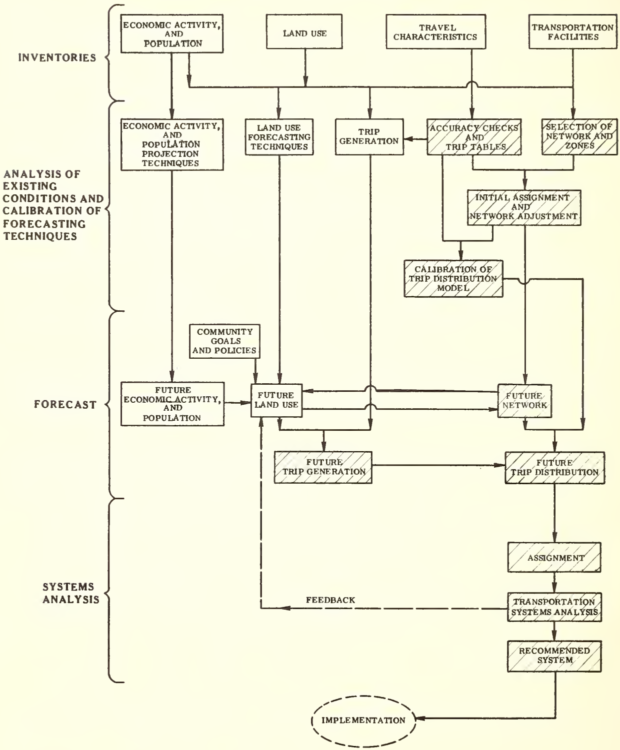

Figure I-1.--Urban Travel Forecasting Process.

resulting revisions are made to the system and additonal future assignments are made to the revised networks. All or part of the traffic assignment and distribution phases are repeated until satisfactory results have been obtained.

C. Trip Distribution

A key element of the analysis and forecasting phase is the development of a reliable procedure that is capable of estimating zonal trip interchanges for alternative configurations of land use and transportation facilities. These zonal interchanges constitute a basic part of the travel information necessary for transportation planning.

The analysis of many origin and destination surveys in relation to the type and extent of the transportation facilities available, the uses of land, and the various social and economic characteristics of trip makers, indicates that zonal trip interchanges can be estimated by the application of mathematical formulas, called "trip distribution models."

The use of such models in transportation planning offers certain advantages over older trip distribution forecasting techniques. Earlier it was suggested that a basic aim of the transportation planning process is to provide decision makers with quantitative information about the consequences of decisions concerning the type, location, size, and timing of transportation improvements. One of the advantages of mathematical travel models is that they serve this aim quite well.

Mathematical trip distribution models provide a common base for simulating the travel patterns that can be expected to result from a variety of different land use configurations coupled with alternate highway systems. This allows the responsible authorities to see, in advance, the probable consequences, in terms of travel patterns, of different combinations of land use and transportation patterns.

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CHAPTER II - INVENTORIES AND DECISIONS	September 1965

A. General

The following sections discuss the information which must be available and the decisions which must be made concerning the data from the various inventories so that it will provide the required results when used in the various phases of the planning process.

B. Travel Pattern Inventory

The procedures described here assume that origin and destination survey data are available in sufficient amounts to provide the following information:

1. Zone-to-zone movements by trip purpose
2. Productions and attractions

In these respects, the standard home interview survey, conducted in a manner as recommended by the Bureau of Public Roads (3), yields the most complete and accurate data. In all cases, sufficient sampling controls must be exercised to assure that the resulting travel data are complete and not statistically biased in any manner.

In addition to a home interview survey of internal travel, an external cordon survey (6) and a truck and taxi survey (7) should also be included to complete the picture of travel in the urban area under study. Other special surveys may be necessary, depending on the area under consideration.

C. Travel Facilities Inventory

Besides sufficient, reliable data on travel patterns, there must also be available several items of information relating to the travel facilities in the area. For the purposes of traffic assignment and gravity model trip distribution, the following data on major sections of the highway and transit facilities in the area are particularly important:

1. Location

2. Physical dimensions

    a. Length

    b. Width

    c. Number of lanes

3. Average speed of travel in both peak and off-peak hours

4. Signalization, parking requirements, direction of travel and other data for capacity calculations

5. Existing traffic volumes

D. Socio-Economic and Land Use Data

In order to provide an effective analysis of travel patterns and trip generation the following data should be available on a zonal basis:

1. Population by age group

2. Average family income

3. Labor force 1/

4. Employment by industry and occupation 2/

5. Land area by type (8)

6. Car ownership

7. Number of dwelling units

These data will provide the information for estimating trip production and trip attraction values.

In the remaining discussions it will be assumed that all the required data have been obtained and are available for use.

1/ "Labor force" refers to workers considered in relationship to their place of residence.

2/ "Employment" refers to workers considered in relationship to their place of work.

E. Initial Decisions to be Made

1. Vehicle trip ADT model.--Once a transportation study has decided on the trip distribution model to be used, in this case the gravity model, there remain many choices as to the manner in which this model is to be used to provide estimates of travel patterns.

Perhaps the first choice is whether the model should distribute total person trips or vehicle trips. The answer to this question is directly related to both the objectives and needs of the study and to the size of the area involved.

In small urban areas, where transit usage is not or will not be very large, the model should be designed for vehicular trips. The procedures described herein can be used to distribute either person or vehicular trips, as desired by the user.

In large urban areas it is generally necessary to analyze different levels of both highway and public transit service in order to arrive at a properly balanced transportation system. For this reason a person trip model is sometimes used. When person trips are distributed between zones either in total or by separate modes of travel, depending on the procedure desired, it is necessary to take into account the modal split and vehicle occupancy rates of these trips prior to assigning them to the transportation system.

2. Peak hour or off-peak hour driving time.--Still another decision must be made concerning the time to be used to indicate the driving time portion of the spatial separation between zones. The selection of peak, off-peak or some combination of these two times depends primarily on the existing congestion conditions in the study area. The decision as to the driving times to be used would depend on whether or not there are large differences between peak and off-peak driving times in any particular segment of the study area. For example, if the ratios of peak to off-peak driving times were about 2.0 for most segments of the transportation system, then this would mean that the relative driving times between the various zones would be about the same, regardless of which times were used. Under such circumstances, it may be best to use off-peak times since about two-thirds of the daily travel occur during the off-peak period.

On the other hand, if certain parts of the transportation system exhibit more congestion during the peak hour than others, then it would be more desirable to use some combination of the peak and off-peak driving times. Several studies have weighted traveltime in the ratio of two-thirds of the off-peak time to one-third of the peak time, since this is about the proportion of travel occuring during these two periods.

3. Trip purpose classification.--A decision must be made as to how many and what combinations of trip purpose categories will be considered in the study. Gravity model trip distributions have been made using as few as one trip purpose and as many as nine or more. There is no clear agreement on this point. The number of purposes is partially a function of

the size of the urban area involved. In selecting the trip purpose classification, it is desirable to take into consideration the volume of trips, the stability of these volumes, and the trip length characteristics for each trip purpose category obtained in the home interview survey. The amount of data preparation time, computer time, and analysis time, must also be considered. It is important that the trip purpose classification system used be designed to sufficiently characterize different travel patterns in the area. On the other hand, it is also desirable that the trip purpose breakdown be realistic from the standpoint of forecasting.

Most of the recent gravity model studies in smaller urban areas have used the following trip purposes and categories with satisfactory results:

a. Home based work trips
Those trips between a person's place of residence and his place of employment for the purpose of work

b. Home based nonwork trips
Those trips between a person's place of residence and all other places except his place of employment

c. Nonhome based trips
Any trip which has neither origin nor destination at a person's place of residence, regardless of its purpose

A study of travel patterns in Sioux Falls, South Dakota (4), indicates that the differences in the accuracy obtained when using six trip purposes, as compared to using the above three purposes, are insignificant in this small area. The computer programs to be used with this manual accommodate only three trip purposes, although more purposes could possibly be used with manipulation of the programs. Generally, in small areas, a three purpose model should be sufficient.

In some large areas where eight general purpose categories have been used, it has been observed that the results could have been improved with even further stratification of shopping trips to distinguish between convenience shopping trips (trips to grocery stores, etc.) and other shopping trips.

4. Treatment of external trips.--Finally the treatment accorded to external trips, trips with one or both ends outside the cordon line, presents the transportation planner with two choices.

First, the external cordon stations could be considered as fictitious zones and assumed to produce and attract trips in a manner similar to the internal zones. In other words, all trips would be treated alike. Generally, it is undesirable to do this for the following reasons:

a. Trips made by those persons living inside the cordon may exhibit different trip length characteristics than those made by persons who live outside the area.

b. External-to-external trips are associated with the study in question for only a small portion of their total journey and therefore exhibit distribution characteristics which have nothing at all to do with the study area.

Second, the total universe of trips could be treated as three distinct types as follows:

a. Trips made within the study area

b. Trips made outside the study area but with one end of the trip inside the cordon

c. Through trips with both ends outside the cordon

For the first type of trips the gravity model can be used directly. For the second type of trips, the gravity model is also used. However, since the trip length characteristics of the second type of trips may be different from those of the first type, a separate gravity model analysis should be made. This decision is particularly important in the smaller urban areas where the proportion of these trips to the total trips in the area is quite large but the total number of trips is small. If the combination of type (a) and (b) trips were used to develop a single set of traveltime factors for a small urban area, the results may be distorted, sending the trips of the first type too far, and the trips of the second type not far enough. Consequently, it is desirable to treat the type (b) trips as a separate trip category and develop a gravity model by treating them as a single purpose.

For the third type of trips, through trips, a growth factor technique such as the Fratar procedure can be used.

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CHAPTER III - DESCRIBING THE EXISTING SYSTEM AND ASSIGNING TRAFFIC	September 1965

Once the trip purpose classifications to be used in the gravity model distribution have been determined, the next decision is the method to be used for assigning traffic. Traffic may be assigned by either an all-or-nothing procedure or by a diversion procedure.

In order to assign the survey trips to the present network, the following operations must be accomplished:

A. Preparation of the network

B. Editing the network

C. Building and checking the minimum path trees

D. Processing the survey trip cards

E. Assigning O-D trips to the present network

A. Preparation of the Network

The travel facilities inventory provides the information which is used for defining the existing network to the computer. The information that is required for each link used in the traffic assignment network is: 1) the link speed or traveltime and the link distance; and 2) the capacity of the link, if a capacity restraint procedure is to be used.

There are several items involved in preparing the network and these will be discussed individually. References will indicate that a more detailed discussion of an item is available in another publication.

1. Map preparation.--Two base maps of the study area are usually required for defining the street and highway system. Another map showing the traffic survey zones and boundaries and their respective zone numbers is used to locate the zone centroids. In addition, appropriately scaled street and highway maps must also be available.

2. Speed and traveltime information.--The speed and traveltime information is used in coding the links making up the transportation network. Normally, distance and speed are coded for each link and the computer calculates the time. The time may also be coded, but this will be more difficult to adjust later, if adjustment is necessary. Reference (1), chapter III, page 20, provides more information on speed and traveltime.

3. Traffic volumes.--Traffic volumes should be obtained for as many streets as necessary to describe the vehicular movements on the existing major street system. This information is not used in describing the network, but it permits the evaluation of the initial traffic assignments.

4. Street capacities.--The capacity of each link in the coded street and highway network must be determined if capacity restraint procedures are to be used. The information from the travel facilities inventory is used in computing the link capacities.

5. The network description.--The traffic volume data, and the speed and traveltime for each link would be coded on the base maps. With this information now available, the network description process can be initiated, as follows:

a. Locate and number the zones and centroids

b. Define the basic transportation network

c. Connect the centroids to the arterial street system

d. Locate and define the nodes

e. Prepare a list of nodes

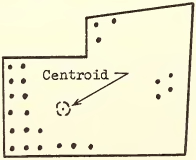
f. Assign the node numbers

g. Set turn penalties and turn prohibitors

h. Define the link parameters

a. Locate and number the zones and centroids.--The establishment of sectors and traffic zones should consider the requirements of the traffic assignment procedure and the related computer programs as well as the requirements for data collection. In addition, planning areas, census tracts, and the requirements with regard to traffic forecasting areas should also be recognized. The trip table builder and trip end summary programs require that the external sectors be numbered higher than the internal sectors.

In a traffic assignment, all trips are assumed to be loaded on the highway network from a single point established for each zone. The point of loading for each zone, defined as a centroid or loading point, should be located at the center of activity for the zone. For a completely residential zone, the center of activity would be the center of gravity of the zone's population. For example, consider the typical zone shown below.



Assuming each spot represents 100 persons, the center of population, or centroid, would be established approximately as shown. For mixed land use zones, such as residential with commercial, the location of the centroid is determined to a large extent by judgment.

The size of the zone must be determined by keeping in mind the statistical stability for sampling, the proper loading for assignment, and the limitations of the computer programs.

On the copies of the zone maps that were previously prepared, the centroid of each zone is located and marked. There is one centroid for each survey zone and external station. They are numbered in a consecutive unbroken sequence beginning with the number 001. A transparent overlay is then placed on the street and highway maps and the centroids with their corresponding numbers are transferred to this overlay.

b. Define the basic transportation network.--The selection of a network for assignment purposes is largely dependent upon knowledge of the area and judgment. The data required for selecting the network are the street classification map, traffic volumes, and street capacities. All streets that carry a substantial volume of traffic should be included. Naturally, a substantial volume means something different in each city. In a large city, it may mean 5,000 vehicles per day. In smaller cities, the number might be 1,000. As a general rule, all expressways and all arterials should be included, as well as a portion of the collector streets. The local streets are not included but are simulated by connections between zone centroids and arterials.

The assignment procedure does not assign intrazonal trips since all trips are loaded to and from a single point, the zone centroid. Therefore, if all streets are included in the system, the assigned volume would tend to be lower than the actual volume counts. On the other hand, if too few streets are included in a network, they would tend to be overloaded; the above factors are compensating to some extent.

In general, a good guide is to include all streets that are protected by a signal or a stop sign. When there is doubt about whether to include a particular facility, it is better to include it than to reject it.

Each facility that is selected for use in the network is traced from the base map on the overlay that contains the centroid locations. Refer to the sample map in figure III-1, the sample network in figure III-2, and the sample base map in figure III-3.

c. Connect the centroids.--Each loading point or centroid must be connected to the arterial street system. Because of computer program restrictions, a centroid can have no more than four connections to the system. As these are hypothetical links that represent the local street system, they are drawn as dashed lines at an angle to the arterial street. Centroids are not normally located directly on a link of the system. If they should fall on a link, they must be relocated adjacent to it and connected by a link of zero traveltime and distance. An option in the computer

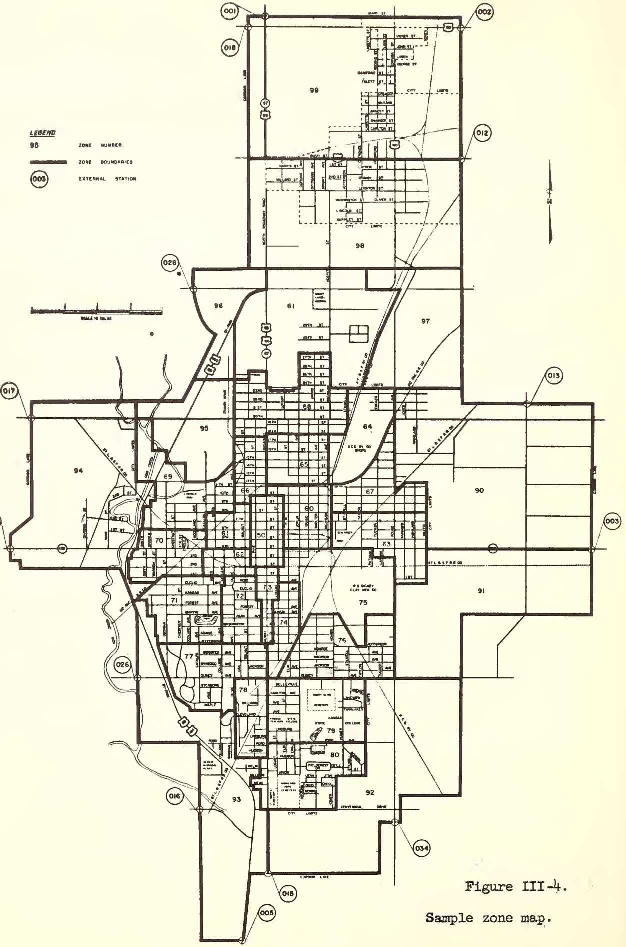


Figure III-4.

Sample zone map.

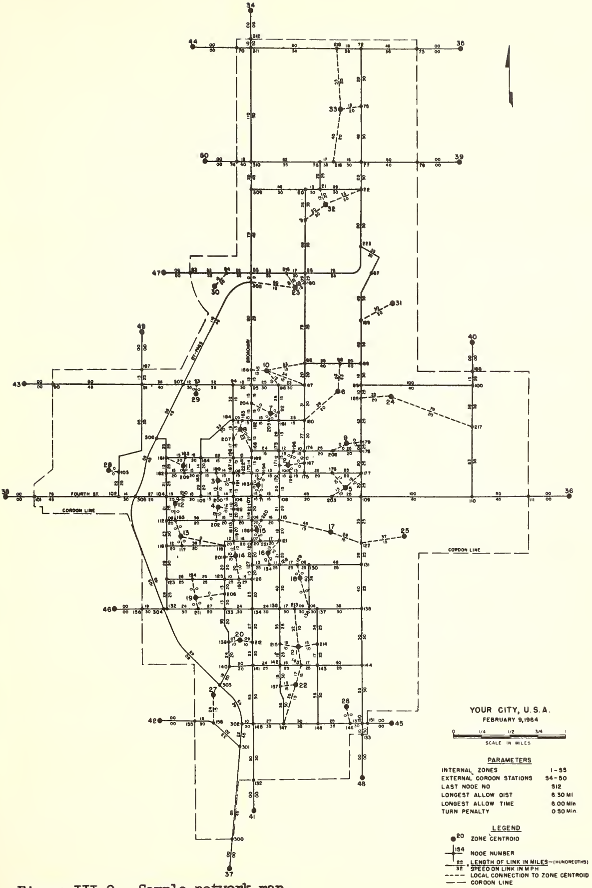


Figure III-2.--Sample network map.

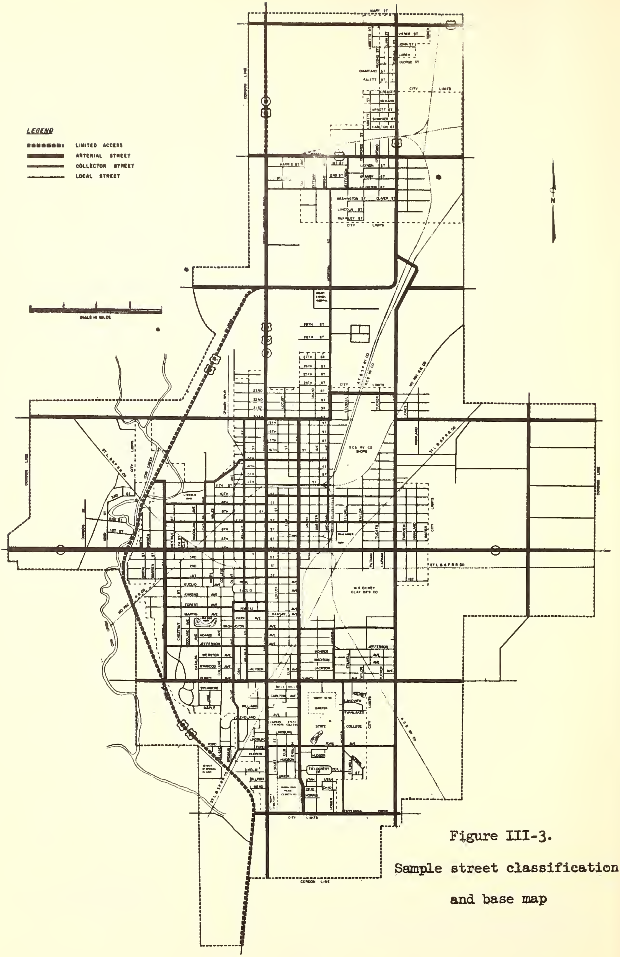


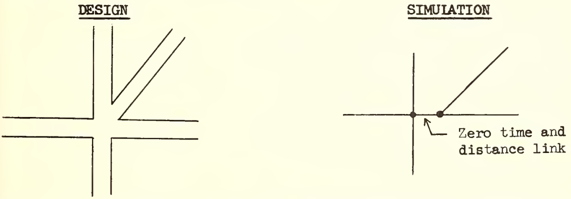
Figure III-3.

Sample street classification and base map

program allows trees to be built through the zone centroids.

It is recommended that a centroid be given connections which are consistent with reality (with a maximum of 4 allowed). More connections tend to smooth the traffic on the adjacent links. If only one connection is given to the centroid, the point at which it connects to the arterial street system will show an abrupt change in traffic volumes. This should be avoided, but for those centroids that represent only a few trips, it may be sufficient to connect them with only one link. When in doubt about the number of connecting links, the larger number of connecting links should be used. The centroid connections are shown on the sample network map in figure III-2.

d. Locate and define the nodes.--A circle or small dot is placed at each intersection in the system to denote the nodes. One of the limitations imposed by the computer program is that there may be no more than four outbound links from a node. When intersections of more than four outbound links are encountered, it is necessary to add extra nodes at the intersection in such a way that none of them has more than four outbound links. The following example shows how this may be done:



If a link is expected to have a traveltime greater than 9.9 minutes, a node or nodes must be inserted in the link so that no link will exceed this limitation. The overall limitations of the computer programs must also be recognized. These are: 1) no more than 100 links are allowed in a minimum time path; 2) a maximum of 699 nodes is allowed in the total present and proposed system and 3) the total time in a minimum path must not exceed 99.4 minutes.

At this point, all one-way streets should be marked with arrows in the direction of travel and, if space is available, some of the major geographical landmarks should be identified such as bridges, major streets, etc.

If the system that is being coded contains some high type facilities, such as freeways, their interchanges may be coded directionally. In directional coding, turning movements and weaving movements may be specified as links in the system. Thus, the longer distance and traveltime in the loops of a cloverleaf interchange may be simulated in a network by directional coding. Some examples of directional coding are illustrated in figure III-4.

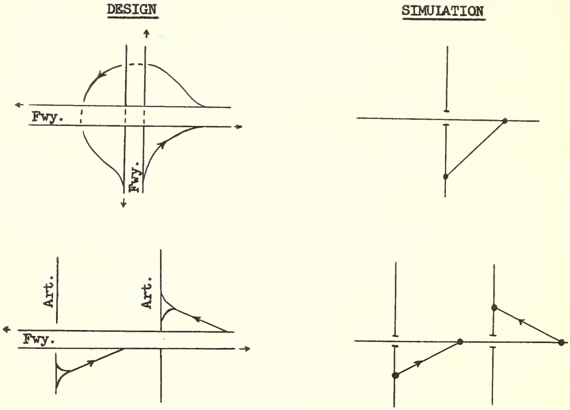


Figure III-4.--Examples of directional coding.

e. Prepare a list of nodes.--Before numbering the nodes that have been previously identified, a list of node numbers is prepared as shown in table III-1. The IBM 1620 tree building and assignment programs require that the centroids be assigned the lowest of four ranges of numbers, beginning with the number 001. The next highest range of node numbers is assigned to the external station nodes. The centroid and station node numbers should be consecutive. The third range of numbers denotes the arterial nodes and the last range of numbers is assigned to the freeway nodes. The highest code number that may be used is 699. There may not be gaps in numbering within a range of nodes. There should be a gap between N_3 and N_4. For proposed systems, a break should not occur between the ranges of arterial node numbers and freeway node numbers (N_5 and N_6). The gaps are provided in this manner so that revisions and corrections to the network may be easily made without destroying the continuity of the

numbering scheme. Proposed arterial street nodes would be added to the lower end of the arterial node range.

Table III-1.--List of nodes

Node group	Range of node numbers
Zone centroids	1 to N_1
Station nodes	N_2 to N_3
Arterial nodes	N_4 to N_5
Freeway nodes	N_6 to N_7 (max. of 140, if used)

where:

$$N_2 = N_1 + 1$$
$$N_3 \leqq 200$$
$$N_7 \leqq 699$$
$$N_7 - N_6 \leqq 140$$

Special note must be made concerning the numbering of the freeway nodes. If a diversion assignment is to be made, a maximum of 140 nodes may be used to describe the proposed street or freeway system. The lowest numbered of the possible 140 nodes must be of a higher number than the zone centroids, station locations, or arterial intersections. In this case, there may be a gap between the arterial and freeway node numbers. There should not be a gap between the arterial and freeway node numbers if an all-or-nothing assignment is to be made for an entire existing system with freeways or a system combining present and proposed freeways. The existing freeways should be coded with the lowest numbers in the freeway node range to facilitate the possible use of a diversion assignment to alternate proposed highway plans. A more detailed discussion of diversion assignment can be found in section E. of this chapter.

If there is no diversion assignment to be made, the computer will make no distinction between arterial and freeway nodes. But, it is still recommended that a definite range of node numbers be assigned to the freeway system. When this is done, there cannot be a gap between the arterial node and freeway node numbers. When coding the ranges of nodes on the computer program control card, the freeway and arterial node numbers are combined into one range of numbers, without a break, and coded as the range of arterial nodes.

With the assignment decision made, the "available node" table is now prepared. It shows all of the node numbers and the node groups to be used in the numbering system. When a number is assigned, it would be removed from the table to prevent the assignment of duplicate node numbers. After the node numbering is completed, the table would be retained to provide

a ready source of available node numbers when making corrections or additions to the network.

f. Assign the node numbers.--Many advantages accrue from adopting a systematic method of assigning node numbers. In general, it has been found best to proceed along the main radial highways, from the center of the urban area outward, and to complete the numbering in the sector between two radials before proceeding to the next. Then the nodes in the same numerical range are grouped together. This facilitates the plotting of trip volumes and other tabulated data during the analysis of the computer runs.

The node numbers may be written either beside the dots representing the nodes or, if preferred, they may replace the dots. Legible writing is critical, as this is the master tracing that will be used throughout the traffic assignment. After completing the numbering, the maps should be reviewed to be sure that every node has been assigned a number.

g. Set turn penalties and turn prohibitors.--In order to provide for turn prohibitors or to penalize certain turning movements, it will be necessary to use four nodes and dummy links. The diagram shown in figure III-5 shows an intersection which required turn prohibitors and turn penalties. It should be noted that turn penalties and prohibitors will reduce the number of available nodes considerably, as they require four nodes per intersection. The following discussion will show the difference between the normal intersection and the one which would require turn prohibitors or turn penalties.

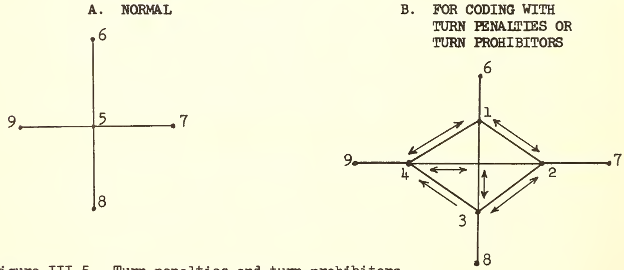


Figure III-5.--Turn penalties and turn prohibitors.

The following example illustrates the method of coding turn prohibitors and turn penalties for the normal intersection shown in figure III-5 A. To begin the process, the intersection node, 5, is eliminated and four nodes are added. Since each link is coded directionally, a turn prohibitor can be coded by just not coding the link in the direction to be eliminated.

To establish a turn prohibitor for the movement from node 4 to node 3, this direction is not coded. The movement from node 3 to node 4 is coded to allow the left turn from the other direction. If the links from node 8 to node 6 were one-way, the movements from node 1 to node 4, node 1 to node 2 and from node 2 to node 3 would also be prohibited by not coding them. A zero time would be coded for each dummy link used. This procedure may not be totally effective, particularly in coding freeway interchanges. See the caution in a following paragraph.

For coding turn penalties, the same configuration of nodes, shown in figure III-5 B, would be used. The only change is that an amount of time is inserted for the dummy link representing the movement to be penalized. Where turn penalties are deemed necessary, the amount of time to be coded would vary with the city. A turn penalty of 0.2 minutes has been used in smaller cities and 0.3 minutes has been used in larger cities.

A caution about using nodes with dummy links for turn prohibitors should be noted here. After test trees have been built, they should be checked to see that the turns have been penalized or prohibited properly. It is entirely possible for the path to use the other dummy links to double back on itself and in effect actually permit a turn at a prohibited location. An example best illustrates this possible problem. Figure III-5 B shows the right turn prohibited in the direction from node 9 to node 8. It is possible for this movement to be duplicated by going from node 4 to node 2 to node 3. If this happens, it will be necessary to adjust the time on each affected dummy link.

h. Define the link parameters.--At this point, the overlays of the network showing the links, nodes, centroids, street names, turn prohibitors, etc. are complete. All further work is done on transparent (reproducible) prints or opaque prints of these maps.

On a print, each link must be defined by its parameters--link distance and speed or traveltime. Dummy links are marked with zero time unless turn penalties are used. Measuring tapes are prepared from tracing paper and marked off in hundredths of a mile for each map scale. The measuring tape is marked with the title and scale of the map with which it is to be used. As each link is measured, the distance is written along the link. Any links which obviously will exceed the 9.9 minute limit for each link must be divided into two or more smaller links by inserting additional nodes.

6. Special treatment for external stations.--If the preceding method was used in coding the network, the links connecting the centroids representing the external stations will be treated by the computer as local streets. As local streets, the vehicle-miles and vehicle-hours of travel on those links will be summarized in the local street category. To avoid this situation, an arterial or freeway node may be placed adjacent to the traveltime and distance link. This has been the usual practice.

Some transportation analysts, however, prefer to code a traveltime for this hypothetical link which represents an average traveltime to or from

that external station and the outlying zones. This will not affect the tree routing, only the summaries of vehicle-miles and vehicle-hours.

Other analysts prefer to treat the external stations by increasing the size of the study area. They remove the external station and extend the network through to the outlying zones, each of which contains a centroid or loading node. This, of course, requires special handling in the building of trip tables and in the preparation of the network. It does permit a "diversion" of the trips approaching the external station, as it gives them a choice of alternate routes to use in entering the study area.

7. Identifying and storing the maps and tabulations.--Each traffic assignment is given an identification number. All of the tracings and prints for a particular system or assignment are kept together in a suitable filing device. Copies of the following tabulations (usually the original copy) are bound in hard covers and preserved for reference:

a. A tabulation of the link data cards used in building the network

b. A tabulation of the link times as built by the computer

c. The tabulation of the link volumes as assigned by the computer

d. If printed, a tabulation of zone-to-zone trips as used by the computer

e. Tabulations of selected trees, and other information

8. Link data card preparation.--This next step involves coding and key punching the link data cards. To prepare for coding, a transparent overlay is placed on the network map and, as each link is coded, it is marked on the overlay. This procedure prevents the coding of duplicate links and permits simultaneous coding by more than one person.

The card type 12 format is required for coding the link data as input to the traffic assignment edit and tree building program, see chapter XI, assignment 1 program description.

9. Checking for errors.--The coding of the network continues until all of the links have been coded and checked. Then the link data cards are keypunched and A node and B node card listings are prepared. The B node listing is prepared first by sorting the link data cards on the first B node field and listing them with tabulating equipment. The cards are then resorted on the A field and again a listing is prepared.

These two listings provide a permanent record of the link data cards and permit a preliminary manual editing of the information. At this time

it is advisable to determine that each centroid has at least one connection to the arterial street system; that there are no more than four outbound links from a node; and that there are no misplaced card punches or illegal codes. Usually a brief scanning of these listings will indicate some errors that should be corrected before any further processing.

If errors are found at this stage, those cards that are in error are removed from the original card deck and replaced by corrected cards. An example of a coded network and its accompanying list of nodes is shown in table III-2.

B. Editing the Network

Before the network can be edited and sample trees built, the type 11 and 14 control cards for the edit and tree builder (assignment 1) program must be prepared (see chapter XI). The type 12 link data cards are used as input data to the program. Enough passes through the program must be made with the control card coded for building only one tree. A description of the control cards and the error messages is included with the program writeup for the assignment 1 program. The cards are examined for the following:

1. Card type numbers and card sequence are checked for validity. Only type 11, 12, and 14 cards are accepted.

2. Each node number is checked and any node coded as zero will be rejected.

3. A message is typed out if more than 140 proposed freeway nodes are specified in card type 11.

4. The low freeway node number is checked for being higher than the other types of nodes when a diversion assignment is indicated.

5. The town code in each card is checked for consistency with card type 11.

6. Each "A" node is checked for being within the specified range of nodes.

7. Each connection to every "A" node is checked and a message is typed out for each connecting node that is outside the specified ranges of nodes.

8. The computed time is checked for being greater than the 9.9 minute maximum link time.

9. The path being built is checked for exceeding the maximum of 99.4 minutes.

Table III-2.--Link data (partial listing) and example list of nodes, Test Town #20

Card type	City code	"A" node	"B" node	Travel speed	Distance	"B" node	Travel speed	Distance	"B" node	Travel speed	Distance	"B" node	Travel speed	Distance
12	20	212	207	30	024	211	22	010	215	25	006	228	28	010
12	20	213	210	25	006	214	23	010	229	25	010			
12	20	214	211	25	006	213	23	010	215	24	010			
12	20	215	212	25	006	214	24	010	231	35	013			
12	20	216	240	35	010	005	37	011	217	35	013			
12	20	217	100	40	020	216	35	013	218	28	003	222	35	032
12	20	218	217	28	003	219	40	028						
12	20	219	218	40	028	220	35	009						
12	20	220	219	35	009	221	30	005	235	40	030			
12	20	221	003	28	007	220	30	005	224	35	025			
12	20	222	217	35	032	203	26	020						
12	20	223	241	40	013	200	30	010	225	27	020			
12	20	224	203	32	010	221	35	025	226	35	020	236	45	030
12	20	225	205	29	010	223	27	020	227	36	024			
12	20	226	207	30	010	224	35	020	228	37	024			
12	20	227	242	24	001	103	40	030	225	36	024	229	30	006
12	20	228	212	28	010	226	37	024	231	32	014	237	45	030
12	20	229	213	25	010	227	30	006	230	35	014			
12	20	230	006	11	017	199	35	028	229	35	014			
12	20	231	215	35	013	228	32	014	233	36	022	238	40	037
12	20	232	199	35	014	243	45	029	006	18	004			
12	20	233	234	35	011	231	36	022	243	45	027	244	40	28

Node group	Node numbers
Zone centroids	001 to 006
Station nodes	100 to 103
Arterial nodes	199 to 238
Freeway nodes	None

10. An error message is typed if the table of nodes yet to be extended is full. This is an indication that there is an error in the system of nodes that permits looping.

11. The reversals of links and their traveltimes are checked, if desired, to see if the opposite direction has been coded and to see if the traveltimes are equal. An error message will be typed out for one-way links as well as links with errors.

12. An error message is typed out if it is impossible to build the selected tree path without using two freeway nodes. The portion of the path involved would be typed out. This test is made only when freeway nodes are specified in the program parameter card.

13. A message is typed out if there is a node within the specified range of nodes for which there are no extensions.

14. A message is typed out if a node specified in the range of nodes is greater than 699.

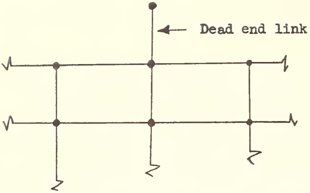
C. Building and Checking Minimum Time Path Trees

After the edit phase has been completed without errors, the program parameter card is changed and selected trees are built using one or more type 14 parameter cards. The same edit and tree building program builds trees and is used to punch any number of the minimum path trees. More than one type 14 card can be used, but the range of nodes punched in each card must be a range of continuous node numbers. As a usual practice, about 6 to 10 trees are built. These sample trees are chosen at the option of the program user, but it is advisable to build at least one tree from a centroid in the central part of the study area and several trees scattered around the peripheral area. This would provide good coverage of the study area for detecting illogical routings caused by network coding errors not checked for in the edit phase.

Some typical errors made in the network coding are shown in figure III-6. One of the most common is the so-called "jumper" which allows the path to jump intermediate links and will short circuit the minimum path.

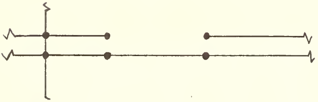
The type 17 existing tree path cards are punched for each pass through the program. This is the reason that only one tree is specified during the editing. To format the cards for tracing and plotting, they are simply listed. To facilitate checking, vertical lines are drawn on the listing to separate the various fields and the fields are marked.

In order to trace an existing tree path, start at the destination node (which is a "B" node) and go continually from the "B" node to the back node until the home node ("A" node) is reached. A sample tree is listed in table III-3, and the following example exhibits how the tree is traced from centroid (home node) 1 to centroid ("B" node) 6. First "B" node 006 is located along with its back node, 232. Second "B" node 232 is located

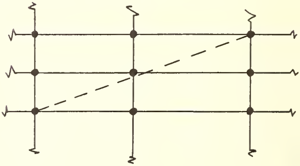


A. Dead end link

B. Link coded in the wrong direction



C. Missing links



D. Jumper link

Figure III-6.--Common coding errors.

along with its back node, 199. Third, go to "B" node 199 and obtain its back node, 230. Fourth, go to "B" node 230 and find its back node, 229. Fifth, "B" node 229 is located and its back node, 227, obtained. Sixth, "B" node 227 is located with its back node 225. Seventh, locate "B" node 225 and its back node, 205. Eighth, locate "B" node 205 and its back node, 204. Next, locate "B" node 204 and it is found that its back node is the home node, 001. This indicates that the tree has been completely traced. Building and tracing trees for the combined existing and proposed system is covered in a later chapter.

The manual plotting of the selected trees would be accomplished at the same time as they are traced. Each tree is plotted on a separate transparent overlay that is placed over the base map. Each link, formed by a "B" node and its back node, that appears in the trace is drawn on the overlay.

A sample plotted tree is shown on figure III-7 for a sample city. Isochronal lines can be drawn on the selected tree traces showing the

Table III-3.--Sample trees, card type 17

Card type	City code	Home node ("A" node of origin)	"B" node	Back node which forms the link with the "B" node	Accumulated driving time from "B" node to "A" node		"B" node	Back node which forms the link with the "B" node	Accumulated driving time from "B" node to "A" node		"B" node	Back node which forms the link with the "B" node	Accumulated driving time from "B" node to "A" node		"B" node	Back node which forms the link with the "B" node	Accumulated driving time from "B" node to "A" node	
17	020	001	001	000	000999	000000	002	208	000217	000000	003	221	000156	000000	004	234	000266	00000
17	020	001	005	216	000220	000000	006	232	000248	000000	100	217	000210	000000	101	240	000230	00000
17	020	001	102	241	000116	000000	103	227	000172	000000	199	230	000211	000000	200	204	000050	00000
17	020	001	201	001	000025	000000	202	201	000046	000000	203	202	000079	000000	204	001	000023	00000
17	020	001	205	204	000066	000000	206	202	000096	000000	207	203	000119	000000	208	209	000181	00000
17	020	001	209	206	000151	000000	210	205	000124	000000	211	210	000156	000000	212	207	000167	00000
17	020	001	213	210	000138	000000	214	213	000164	000000	215	212	000181	000000	216	217	000202	00000
17	020	001	217	222	000180	000000	218	217	000186	000000	219	220	000166	000000	220	221	000151	00000
17	020	001	221	224	000141	000000	222	203	000125	000000	223	200	000070	000000	224	203	000098	00000
17	020	001	225	205	000087	000000	226	224	000132	000000	227	225	000127	000000	228	226	000171	00000
17	020	001	229	227	000139	000000	230	229	000163	000000	231	228	000197	000000	232	199	000235	00000
17	020	001	233	231	000234	000000	234	233	000253	000000	235	236	000178	000000	236	224	000138	00000
17	020	001	237	236	000197	000000	238	237	000245	000000	239	000	000999	000000	240	216	000219	00000
17	020	001	241	223	000090	000000	242	227	000130	000000	243	233	000270	000000	244	233	000276	00000
17	020	002	001	201	000217	000000	002	000	000999	000000	003	221	000266	000000	004	234	000230	00000

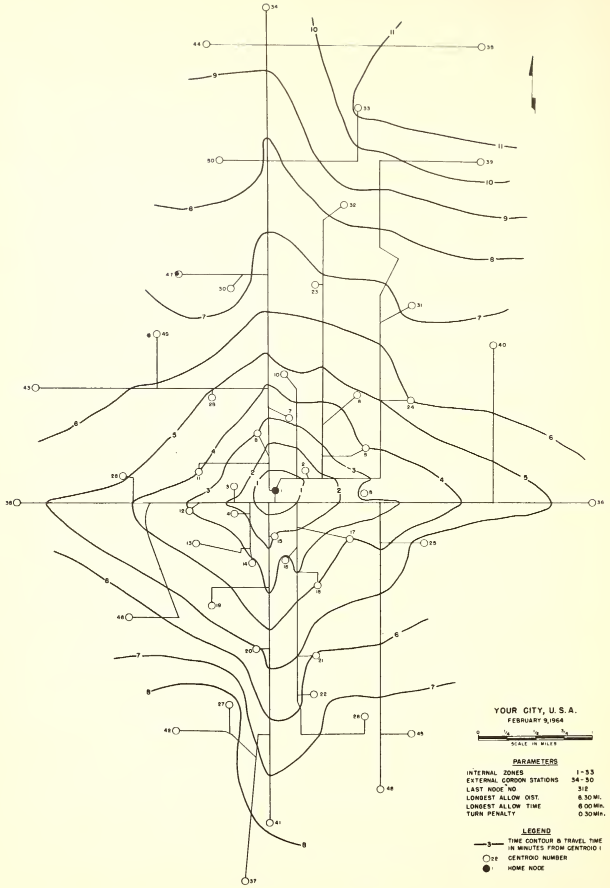


Figure III-7.--Sample plotted tree with contour lines of equal driving time.

equal time contours. These contours may be compared to the traveltime data collected during the inventory. It is also possible to show the traffic "drainage area" for particular sectors of the study area. These indicate how the traffic drains from corridors to the selected centroid.

The principal reason for plotting these selected trees, however, is for the examination of network coding errors and illogical routing. Each tree should be examined for faulty traces, jumpers, and other inconsistencies (see figure III-6). This is the last edit check prior to loading the network with the trips. If the network is free of errors, the process may be continued through the loading of the network.

The plotting of selected trees may reveal that, in some instances, the true minimum time path has not been determined. This condition is usually caused by the addition of turn penalties and turn prohibitors to the network. This does not mean that turn penalties and turn prohibitors always force the computer to build a tree this way. However, the computed minimum time paths should be examined for illogical routings, and the turn penalties and prohibitors adjusted (added, changed, or removed) when necessary.

Illogical routings involving high speed or low speed links may be discovered. If the minimum time path criterion is used alone and a particular freeway is coded with a speed of 50 to 60 m.p.h., it may attract circuitous routings which are unlikely in reality. Thus, the freeway speed should be reduced to, say 40 to 50 m.p.h.

Conversely, traveltime runs may indicate speeds of 10 m.p.h. or less in the central business district. If this speed is coded on CBD links, the computer minimum time path routings may unrealistically avoid the CBD. In this case, the very low speed links may have to be coded at a somewhat higher value to obtain realistic routings.

It should be noted that route selection is based on elapsed time, i.e., minutes per mile. This may be illustrated in the following manner:

Speed (m.p.h.)	Minutes/mile
60	1.0
40	1.5
30	2.0
24	2.5
20	3.0
15	4.0
12	5.0
10	6.0
9	7.0
8	8.0

Note that a difference of 1 minute/mile results in a change in speed of 30 m.p.h. at the upper range of the table, and only 1 to 2 m.p.h. at the lower range.

When any errors in the network have been corrected, the correct deck of type 02 link time cards is then obtained. The next step in the assignment of trips to the present system is the preparation of the origin-destination survey trip cards. However, there are two things which should be noted at this time:

1. A deck of link time cards (type 02) is punched out for each run of the traffic assignment 1 program as a network description. The link time decks from any edit runs should be discarded except for the pass of the program which produced no errors. The type 02 link time cards are used as input to traffic assignment program 2. Examples of the type 02 cards are shown in table III-4.

2. The edit and tree builder program also produces the skim trees required by the update skim trees and gravity model programs. Skim trees are the driving times from each centroid to every other centroid. The assignment 1 program requires a separate run (with one type 14 card coded with the entire range of centroids and stations) of the program to obtain the skim trees. There are no type 02 cards produced when punching the skim trees (type 24).

D. Processing the Survey Trip Cards

The processing of the survey trip cards begins after the volume counts across the screenlines have been checked against the survey and the trip factors have been punched into the survey cards. The decision concerning the trips to be used in the gravity model has previously been made (refer to chapter II).

After selecting the basic travel data for which gravity models will be calibrated, it will be necessary to do the editing, sorting, linking, and separating of the trip cards before building trips tables for assignment. Each of these steps will be explained in turn.

1. Selecting trip cards.--The first step is to select the basic trip cards. This information is selected from the various field inventories to reflect the decisions previously made as to the specific form of the gravity model that will be developed.

All the information collected in the travel pattern inventory is assumed to have been verified, coded, and punched into detail trip cards. The information in the detail trip cards from each of the inventories (i.e., home interview, external cordon, and truck and taxi) must be compatible, though the format of the cards may vary. Depending on the decisions reached on the questions raised in a previous chapter, certain of these detail trip cards must now be selected for further processing. The resulting cards are the ones which will be used in calibrating the gravity models. The data would be selected in accordance with the criteria described in chapter II, section E.4. In most cases, each of the three basic data sources are processed separately. The internal and internal-external trips can be processed as outlined in subsequent chapters of

Table III-4.--Type 02 cards, link times

Card type	City code	"A" node		"B" node		Link time, x.x minutes		"B" node		Link time, x.x minutes
02	020	200	000	201	0000	25	00C000000	204	0000	27
02	020	201	000	001	0000	25	000000000	200	0000	25
02	020	202	000	201	0000	21	000000000	203	0000	33
02	020	203	000	202	0000	33	000000000	207	0000	40
02	020	204	000	001	0000	23	000000000	200	0000	27
02	020	205	000	204	0000	43	000000000	206	0000	46
02	020	206	000	202	0000	50	000000000	205	0000	46
02	020	207	C00	203	0000	40	000000000	206	0000	33
02	020	208	000	002	0000	36	000000000	209	0000	30
02	020	209	C00	206	0000	55	000000000	208	0000	30
02	020	210	000	205	0000	58	000000000	211	00C0	32
02	020	211	000	209	C000	34	000000000	210	0000	32
02	020	212	000	207	0000	48	000000000	211	0000	27
02	020	213	000	210	0000	14	000000000	214	0000	26
02	020	214	C00	211	0000	14	000000000	213	0000	26
02	020	215	000	212	0000	14	000000000	214	0000	25
02	020	216	000	005	0C00	18	000000000	217	0000	22
02	020	217	000	100	0000	30	000000000	216	0000	22

"A" node		"B" node		Link time, x.x minutes		"B" node		Link time, x.x minutes	
200	000000000	223	0000	20	000000000	000	0000	00	00000
201	000000000	202	0000	21	000000000	000	0000	00	00000
202	000000000	206	0000	50	000000000	000	0000	00	00000
203	000000000	222	0000	46	000000000	224	0000	19	00000
204	000000000	205	0000	43	000000000	000	0000	00	00000
205	000000000	210	0000	58	000000000	225	0000	21	00000
206	000000000	207	0000	33	000000000	209	0000	55	00000
207	000000000	212	0000	48	000000000	226	0000	20	00000
208	000000000	000	0000	00	000000000	000	0000	00	00000
209	000000000	211	0000	34	000000000	000	0000	00	00000
210	000000000	213	0000	14	000000000	242	0000	23	00000
211	000000000	212	0000	27	000000000	214	0000	14	00000
212	000000000	215	0000	14	000000000	228	0000	21	00000
213	000000000	229	0000	24	000000000	000	0000	00	00000
214	000000000	215	0000	25	000000000	000	0000	00	00000
215	000000000	231	0000	22	000000000	000	0000	00	00000
216	000000000	240	0000	17	000000000	000	0000	00	00000
217	000000000	218	0000	06	000000000	222	0000	55	00000

this volume. The processing of the through trips (both ends outside the cordon) is not covered in detail in this volume; however, a discussion of the Fratar trip distribution is included for use with these trips. See chapter IX.

All trip cards (i.e., those from the home interview, external cordon, and truck and taxi surveys) are first edited, sorted, and linked, as will be described shortly, and then the basic trip cards to be analyzed can be selected.

2. Editing trip records.--The next step is to edit the selected data. In any analysis which uses the survey data, it is always desirable to edit the information to insure that it has been correctly coded and punched. If the source data are not rigidly controlled and edited, it is possible that the data will be distorted and much useless analysis will result. Also, when using the system of programs described in this volume some of the IBM 1620 programs have internal controls which reject trip records when they contain certain unacceptable information. To avoid these costly problems and to permit smooth processing in later phases of model development, all trip cards are edited.

Several items of data should be edited for unacceptable card punches. Some of the items more pertinent to the programs described in this volume are:

a. Is card number correct? It should be 1 for the dwelling unit cards; 2 for the home interview survey trip cards, etc.

b. Are all card punches within acceptable limits? For example, there should be no month number greater than 12 or outside the season in which the surveys were conducted; the "start" time and the "end" time for all trips must both be on the same day and the "end" time must be later in the day than the "start time;" no purpose code should contain alphabetic punches. The specific limits vary from study to study.

c. Are there any numerical or alphabetical punches in columns which should be blank, or are there alphabetic punches in columns which should contain numerical punches or vice-versa?

d. Do the zone numbers fall within the maximum number of zones in the study area?

e. Is the residence zone the same as the origin or the destination zone if the "from" or "to" purpose is home?

f. Are there any duplicate cards?

These items and others should be checked in the edit process. For a more complete listing of items which may be edited, see the "Contingency Check Manual," Niagara Frontier Transportation Study (9).

The editing can be done with the use of EAM equipment. Programs may be written for the computer, or existing programs may be used (such as the

GM 501 or 502 Edits available from the Bureau of Public Roads for the 16K IBM 1401 computer).

3. Sorting and linking trip cards.--Because of the standard origin-destination survey definition of a trip[1], many journeys made by a trip maker have to be represented by two or more trip cards even though only one journey is involved. In an origin-destination survey, one trip ends and another begins every time a person changes his mode of travel, an auto-driver stops to serve a passenger, or when the trip maker reaches his ultimate destination. In the first two cases, if each of these trips were analyzed separately, the relationships between the actual starting point, the ultimate destination, and the purpose of the trip would be lost. It also would be difficult to relate the type and intensity of trip making to the type and intensity of the use of land. Consequently, it is desirable to combine or "link" those trips which have a "purpose to" or "purpose from" of either "change mode of travel" or "serve passenger" so that the relationship between the purpose of the trip and the ultimate destination of the trip is preserved.

Trip linking is not necessary in all cases. In urban areas, for example, where "change mode" trips may be small in number because of the lack of transit facilities and where "serve passenger" trips may also be small in number because of the absence of car pooling, trip linking may not be necessary. For analysis purposes, trips of this type can often be combined with other trip purposes with no significant loss in accuracy. However, in larger areas, it is generally desirable to accomplish the trip linking process.

If the decision is made to link trips, the following discussions will provide the procedures to follow in the linking process.

For the particular system outlined in this volume, the sample number is the primary sort field and the person number and trip number are the secondary sort fields. This step is necessary to detail the trip pattern of each trip maker in the order in which the trips were made on a particular day. This is required in order to "link" trip cards. The sorting operation can be accomplished by using EAM equipment, a sort program for the IBM 1620, or with a sort program on a different computer.

Some examples of those trips which might be combined or "linked" are shown in figures III-8 and III-9.

Figure III-8 illustrates an auto driver driving his car from home to a fringe area parking lot where he boards a bus and rides to work. In an origin-destination survey the first trip would be recorded as an "auto-driver" trip from "home" to "change mode of travel." The second trip would be recorded as a "transit passenger" trip from "change mode of travel" to "work." Since the ultimate purpose of this journey was to

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1/ A trip can be defined as the one-way travel between two points for a specified purpose.

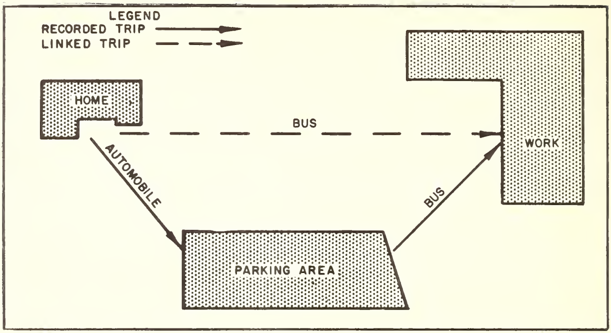

Figure III-8.--Example of trip linking.

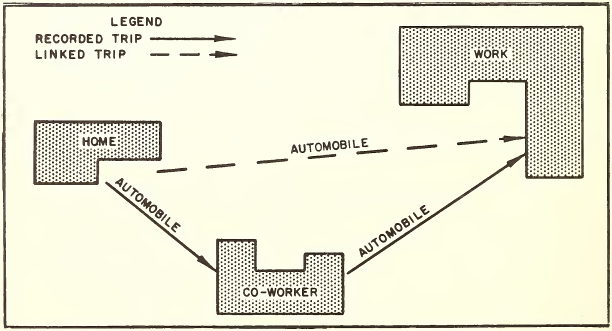

Figure III-9.--Example of trip linking.

get from home to work, it is desirable to "link" these two trip records into one which covers the entire journey. This particular case would become a home to work trip since this was the ultimate purpose of the trip. The mode of travel would be bus, the assumption being that if satisfactory bus service had been available at the trip maker's home, he would have used it. Mode of travel is generally assigned according to a priority which lists transit before automobile. Regardless of the phase of the journey, the mode used which is of highest priority is assigned to the "linked" trip.

A similar situation is shown in figure III-9. A person drives his car from home to the home of a co-worker and they both proceed to work. In this case, the auto driver's journey would be recorded as two separate auto-driver trips, the first one from "home" to "serve passenger" and the second one from "serve passenger" to "work." Since the auto-driver's ultimate purpose was to get to work, it is again desirable for analysis purposes to "link" these two trip cards into one which covers the entire journey. In this case, the "linked" trip would become a home to work trip by automobile, based on the same reasoning as the previous example.

There are two cases in the linking process which require special handling. The first of these occurs, for example, when a wife drives her husband to work and then returns home. The "linked" card on this journey would show an invalid home-to-home trip for the wife, provided the normal process was followed. These are handled separately. The purpose "to" on the first trip card and the purpose "from" on the last trip card are changed to the "personal business" code. The second case which is handled separately applies to those trips which have only one trip card. For example, a trip by a person who changes mode of travel at an airport or railroad station and leaves the city and doesn't return that day would be recorded in an origin-destination survey as only one trip with a purpose to a "change mode of travel." The one trip card is used as the "linked" trip card after changing the "change mode of travel" code to the "personal business" code. The final "linked" trip cards are then combined with those cards which did not require linking. These trip cards are then used in any subsequent analysis work to be performed.

The trip linking process causes a decrease in both the absolute number of "trips" taking place (although there is no decrease in the number of journeys taking place) and in the total vehicle miles (or hours) of travel in the urban area. The exact amount of the decrease in the number of trips can be determined by simple subtraction of the number of trips in the "linked" cards from those in the "unlinked" cards. The slight decrease in vehicle-miles of travel can be obtained by assigning both the "linked" and the "unlinked" trips to a comprehensive highway network and subtracting the two resulting vehicle-miles of travel. From an analysis of past studies, it appears that the decrease in trips and the lesser decrease in vehicle-miles of travel have little effect in the transportation planning process provided this loss is not concentrated in any one part of the urban area.

4. <u>Separating trip cards by purpose</u>.--Up to this point, all those cards originally selected for analyses purposes have been processed with little regard to purpose or mode of travel. However, during the gravity model calibrating and testing process it is important to deal with the trips by purpose or travel mode category. Past research (2),(4) has indicated that the effect of spatial separation on trip interchange varies by trip purpose and travel mode category. In addition, zonal trip production and trip attraction values are determined on the basis of various types of land uses which have been shown to correlate with trips by purpose. Consequently, the next step is to separate the trip cards by general purpose or travel mode category.

The separation process is done on EAM sorting equipment. There are normally 10 purpose "to" and purpose "from" codes used in the trip cards.

Code	Purpose
0	Home
1	Work
2	Personal business
3	Medical-dental
4	School
5	Social-recreational
6	Change travel mode
7	Eat meal
8	Shop
9	Serve passenger

Separating the trip cards into the three general purposes is accomplished by sorting on the purpose "to" and purpose "from" card columns. The IBM 1620 computer programs are designed to use only three general purposes as follows:

Code	General purpose
01	Home based work
02	Home based nonwork
03	Nonhome based

Sorting out the home based trips is done by separating all trips with a zero, "0" in either the purpose "to" or "from" columns. The remaining trips from this sort are the nonhome based trips The home based trips are then sorted for a "1" in either the purpose "to" or "from" card columns. The cards with a "1" coded in either column are home based work trips and the remainder are home based nonwork trips.

Once the trip cards have been separated into three decks of cards (for those categories of trips for which separate gravity models will be calibrated and tested) the basic trip data are in the proper form for building trips as will be discussed in the next section.

One item to be noted at this point is that two of the general trip purposes will be referred to in abbreviated form for the remainder of this volume. Home based work trips will be referred to as "work" trips and home based nonwork trips will be referred to as "nonwork" trips.

5. Building the trip tables.--The trip table builder program combines two tasks into one. It will recode five-digit subzone numbers to three digit centroid numbers and then round six-or seven-position traffic volume totals to five-position totals. Second, it will build the trip tables necessary for adding trip tables, assigning the trips and developing the origin-destination trip length frequency distributions.

This program will accept either trip card type 2, 3, 4, or 5. The format for each card type must be described for the computer on a parameter card. The card formats are described in the program descriptions.

The card output of the trip table builder are the stacked volume cards (type 03) or trip tables. These trip tables, by purpose, will have to be combined before assigning the trips to the present network. The combined trip table is obtained with the add trip tables program. The operation of this program is covered in the program description.

E. Assigning O-D Trips to the Present Network

After the O-D trip tables for each purpose have been added together, the total purpose trip table is ready for the initial assignment to the present network using the assignment 2 program.

At this point, there has been no adjustment of the network other than correction of coding errors, and the minimum path trees have been built on the basis of the traveltimes coded into the network. No attempt has been made to account for other conditions that may affect the route choice between two points, such as: congestion, pedestrian interference, pavement condition, etc.

The initial assignment to the present network is usually done on an all-or-nothing basis. The output of the all-or-nothing assignment is the directional and nondirectional link volumes. Examples of an all-or-nothing assignment are shown in tables III-5 and III-6.

Table III-5.--Directional assignment type 04 cards

Card type	City code	"A" node		"B" node (1)	Directional link volume		"B" node (2)	Directional link volume		"B" node (3)	Directional link volume		"B" node (4)	Directional link volume	
04	020	203	000	202	003541	000000000	207	000000	000000000	222	000000	000000000	224	000432	000000
04	020	204	000	001	006553	000000000	200	004100	000000000	205	009119	000000000	000	000000	000000
04	020	205	000	204	006553	000000000	206	000000	000000000	210	000000	000000000	225	009119	000000
04	020	206	000	202	004375	000000000	205	000000	000000000	207	001234	000000000	209	009660	000000
04	020	207	000	203	000000	000000000	206	001010	000000000	212	000000	000000000	226	001234	000000
04	020	208	000	002	014366	000000000	209	014366	000000000	000	000000	000000000	000	000000	000000
04	020	209	000	206	005609	000000000	208	014366	000000000	211	008757	000000000	000	000000	000000
04	020	210	000	205	000000	000000000	211	004650	000000000	213	000000	000000000	242	008421	000000
04	020	211	000	209	004706	000000000	210	008421	000000000	212	000000	000000000	214	000336	000000
04	020	212	000	207	000000	000000000	211	000000	000000000	215	000000	000000000	228	000000	000000
04	020	213	000	210	000000	000000000	214	000000	000000000	229	000000	000000000	000	000000	000000
04	020	214	000	211	000056	000000000	213	000000	000000000	215	000336	000000000	000	000000	000000
04	020	215	000	212	000000	000000000	214	000056	000000000	231	000336	000000000	000	000000	000000
04	020	216	000	005	020868	000000000	217	002994	000000000	240	017874	000000000	000	000000	000000
04	020	217	000	100	000000	000000000	216	000106	000000000	218	002994	000000000	222	000000	000000

Table III-6.--Nondirectional assignment type 05 cards

Card type	City code	"A" node		"B" node (1)	Nondirectional link volume		"B" node (2)	Nondirectional link volume		"B" node (3)	Nondirectional link volume		"B" node (4)	Nondirectional link volume	
05	020	200	000	201	007832	000000000	204	004100	000000000	223	011932	000000000	000	000000	000000
05	020	201	000	000	000000	000000000	000	000000	000000000	202	016998	000000000	000	000000	000000
05	020	202	00C	000	000000	000000000	203	003973	000000C00	206	013025	000000000	000	000000	000000
05	020	203	000	000	000000	000000000	207	000000	000000000	222	000000	000000000	224	003973	000000
05	020	204	000	000	000000	000000000	000	000000	000000000	205	015672	000000000	000	000000	000000
05	020	205	000	000	000000	000000000	206	000000	000000000	210	000000	000000000	225	015672	000000
05	020	206	000	000	000000	000000000	000	000000	000000000	207	002244	000000000	209	015269	000000
05	020	207	000	000	000000	000000000	000	000000	000000000	212	000000	000000000	226	002244	000000
05	020	208	000	000	000000	000000000	209	028732	000000000	000	000000	000000000	000	000000	000000
05	020	209	000	C00	000000	000000000	000	000000	000000000	211	013463	000000000	000	000000	000000
05	020	210	000	000	000000	000000000	211	013071	000000000	213	000000	000000000	242	013071	000000
05	020	211	000	000	000000	000000000	000	000000	000000000	212	000000	000000000	214	000392	000000
05	020	212	000	000	000000	000000000	000	000000	000000000	215	000000	000000000	228	000000	000000
05	020	213	000	000	000000	000000000	214	000000	000000000	229	000000	000000000	000	000000	000000
05	020	214	000	000	000000	000000000	000	000000	000000000	215	000392	000000000	000	000000	000000
05	020	215	000	000	000000	000000000	000	000000	000000000	231	000392	000000000	000	000000	000000
05	020	216	000	000	000000	000000000	217	003100	000000000	240	038636	000000000	000	000000	000000
05	020	217	000	000	000000	000000000	000	000000	000000000	218	003100	000000000	222	000000	000000
05	020	218	000	000	000000	000000000	219	003100	000000000	000	000000	000000000	000	000000	000000
05	020	219	000	000	000000	000000000	220	003100	000000000	000	000000	000000000	000	000000	000000
05	020	220	000	000	000000	000000000	221	003100	000000000	222	000000	000000000	235	000000	000000

Also, the assignment 2 program checks for the following error conditions:

1. Card type numbers are checked. Only type 01, 02, and 03 cards are accepted.

2. The city code in each card is checked against the first card.

3. The minimum time path being built is checked for exceeding the maximum of 99.4 minutes.

4. If the table of nodes yet to be extended is full, an error message will be typed. This is an indication that there is an error in the system of nodes that permits looping.

5. The existing or proposed tree path is checked for containing more than 100 links.

6. The origin and destination zone of the volume card (type 03) are checked for being within the range of nodes.

The initial loading (assignment) is usually analyzed by transferring the assigned volumes from the assignment program output to a print of the network map. This procedure is time consuming and usually, only the volumes on major facilities are investigated initially.

The assigned volumes may then be compared with the ground counts and with existing link capacities. The assigned volumes may be considerably different from ground counts or link capacities, because of the previously mentioned conditions affecting route choice between two points.

If there are no errors found in the loaded network, the analyst may now want to restrain the assignment or to make a diversion assignment.

Restraining a traffic assignment, refers to adjusting the link parameters (traveltime or speed) to account for factors other than traveltime in the choice of a route. Prior to adjusting an assignment, the minimum time path is chosen strictly on the basis of an average speed or a known traveltime on a link. After adjustment, these traveltimes become a measure of the travel restraint. If the assigned volume is low, the speed on the link is increased, making the route more attractive during the next assignment. If the link is overloaded, the speed is decreased (or traveltime increased) to make the link less attractive.

An assignment restraint may be done by either of two methods: manually or with a capacity restraint computer program.

In order to restrain an assignment when using the battery of program described in this publication, the manual method must be used or a program must be written. To restrain an assignment with an existing capacity restraint computer program, a different battery of programs must be used. It should be noted, however, that one cannot combine this

IBM 1620 program battery with the other batteries of Bureau of Public Roads' programs due to different methods being used in coding the networks.

The manual restraint of a traffic assignment is a process of deciding what adjustments are necessary for the network, coding and keypunching the necessary cards, and rerunning the assignment programs. A new assignment is made to the revised network, and the new assignment would be analyzed. This process of revising the network is continued until the traffic is satisfactory. It is evident that this manual restraining is very time-consuming and costly. For the larger systems, where capacities are available for most links in the system, it is advisable to avoid manual restraining and allow a computer to make the adjustments. Capacity restraint programs are available in other batteries of programs, such as the traffic assignment program battery for the IBM 7090/7094. The theory of capacity restraint is briefly described in reference (1), pages V-18 to V-21.

Diversion assignment is sometimes used after the initial all-or-nothing assignment in order to properly assign traffic to an existing network which includes some freeways. If diversion assignment is to be used, the network must have been coded with the freeway nodes in the correct range, see table III-1.

The diversion option of the assignment 2 program uses the Bureau of Public Roads' diversion curve as the basis for its diversion assignment. The Bureau of Public Roads' time ratio curve bases the percentage of trips to be assigned to a freeway facility on the ratio of the traveltime via the freeway to the traveltime via the quickest alternate route. The percentage of trips using the freeway varies as a S-shaped curve from 100 percent at a time ratio of 0.5 or less to zero percent at a time ratio of 1.5 or more. For a time ratio equal to 1.0, approximately 42 percent of the trips are assigned to the freeway. Only 42 percent is assigned because the freeway trips, with the faster speed, require a longer travel distance. This diversion curve (as shown in figure III-10) has been developed to allow reasonable diversion to freeways when only short sections of a freeway are used in a longer routing.

Diversion assignments have sometimes required adjusting times on freeway links. This was necessary in order to force the use of freeway facilities for a portion of each zone-to-zone minimum path movement. The diversion assignment option in the assignment 2 program takes into account the future freeway links and eliminates the need for adjusting times to obtain minimum paths using freeway links. This program calculates one minimum path using the arterial nodes only and then computes the second minimum path using at least two freeway nodes. The computer program forces the use of freeway links in determining this second path and eliminates the probability of ending up without a minimum path where the freeway path has a longer driving time than the arterial path. If minimum paths longer than the arterial minimum path were not allowed, there would be no time ratios greater than 1.00 and the upper portion of the diversion curve would be useless. If forcing a path to use freeway links results in a very high time ratio, it is disregarded, because any ratio greater than the upper limit results in no assignment

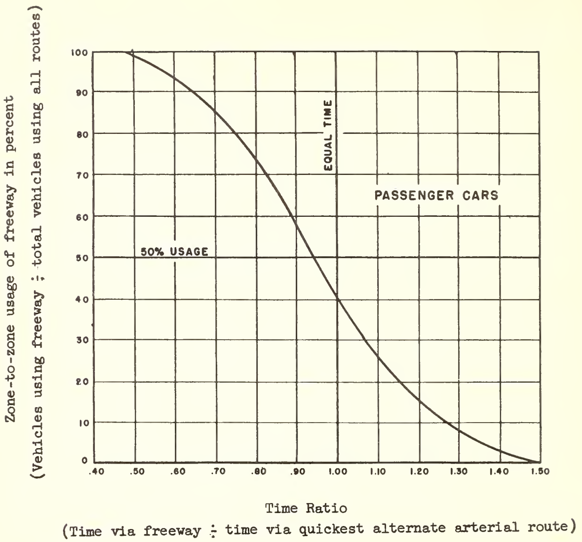

Figure III-10.--Bureau of Public Roads' diversion curve.

to the freeway path for that particular zone-to-zone movement.

A diversion assignment can be obtained by following the instructions for the options in the assignment 2 program description. This diversion assignment provides turning volumes for only those nodes in the freeway node range. If turning movements are desired for an arterial system node (nonfreeway node), this node must be coded with a node number from the freeway node range without any connection to another node in this same range.

Having obtained a satisfactory assignment of the O-D volumes, the next step is to simulate the existing travel patterns using the gravity model trip distribution formula. This is covered in the next chapter.

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BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

CHAPTER IV - THE GRAVITY MODEL	September 1965

A. The Gravity Model Formula

The gravity model is a mathematical formula for distributing trips in an urban area. It parallels the gravitational concept as advanced by Sir Isaac Newton. A history of the model is found in reference (2). The theory behind the gravity model is expressed as follows: Trip interchange between zones is dependent upon the relative attraction of each of the zones and upon a function of the spatial separation between zones.

The gravity model formula is expressed mathematically as follows:

$$T_{ij} = \frac{P_i \; A_j \; F_{ij} \; K_{ij}}{\sum_{j=1}^{n} A_j \; F_{ij} \; K_{ij}}$$

where: T_{ij} = Trips produced by zone i and attracted to zone j

P_i = Trip production by zone i

A_j = Trip attraction in zone j

F_{ij} = Empirically derived traveltime factor which expresses the average areawide effect of spatial separation on trip interchange between zones t_{ij} apart

K_{ij} = A specific zone-to-zone adjustment factor to allow for the incorporation of the effect on travel patterns of defined social or economic conditions not otherwise accounted for in the gravity model formula

and where T_{ij}, P_i, and A_j are defined below.

The parameters in the formula are developed individually for each urban area under study. Moreover, these parameters are developed for each trip purpose category, see chapter II, section E.

B. Definitions of Parameters

1. Trip production and trip attraction.--From the gravity model formulation shown previously, it can be seen that five separate parameters are required before the trip interchanges (T_{ij}) can be computed. Two of the basic parameters are concerned with the use of the land in the study area and with the social and economic characteristics of the people who make trips. These parameters are the number of trips "produced" (P_i) and the number of trips "attracted" (A_j) by each traffic zone in the study area.

Trip productions for home based and nonhome based trips are defined differently. For trips with either the origin or destination at the trip makers' residence (home based trips), the trip ends in the residence zone are considered trip productions. For trips with neither end at the residence (nonhome based trips), the origin ends are considered trip productions.

Trip attractions are also defined differently for home based and nonhome based trips. For trips with either the origin or destination at the trip makers' residence (home based trips), the trip ends in the nonresidence zone are considered trip attractions. For trips with neither end at the trip makers' residence (nonhome based trips), the destination ends of these trips are considered trip attractions.

As an illustration of the differences between zones of origin and destination and zones of production and attraction consider the following example. A person lives in zone A and travels to work in zone B in the morning and returns directly home in the evening. An origin-destination survey report on these trips would show that this person left his home in a zone of origin (zone A) in the morning and went directly to work in a zone of destination (zone B). For the return trip it would show that this person left his work place in a zone of origin (zone B) and went directly to his home in a zone of destination (zone A). In those traffic models which distribute one-way trips, each of these two trips are distributed by a separate calculation, each from its zone of origin to its zone of destination.

Since the gravity model distributes productions to attractions, these two trips are handled somewhat differently. Consequently, zone A would be credited with having produced two work trips and zone B would be credited with having attracted two works trips. Both work trip productions would then be distributed from the zone of production, zone A, to the zone of attraction, zone B.

At any given time, the total number of trips produced by and attracted to each traffic zone within an urban area can be determined with reasonable accuracy by a properly designed and conducted home interview origin-destination survey (3). Estimates of future trip production and attraction can be determined by reference to the relationships that can be derived between existing home interview trip data and a particular existing land use or social-economic factor or a combination of these factors.

2. Spatial separation between zones.--The spatial separation between zones can be measured in several ways. To date, the most effective measure seems to be traveltime.

The total traveltime between zones is composed of the minimum path driving time between zones plus the terminal time at both ends of the trip. Terminal time at both ends of the trip is added to driving time to allow for differences in parking and walking times in these zones, as caused by differences in congestion and parking facilities. This adjusts driving time to a more realistic measure of the actual spatial separation between zones.

For any study period, the minimum path driving time between each pair of zones is obtained with the edit and tree builder program. The data processed by the tree builder program are taken from a field survey which records the distance and speed of travel over major routes of the transportation system. These data are used in preference to the trip times reported in the travel pattern inventory because people tend to report traveltime to the nearest 15 minutes even when asked to specify time to the nearest minute. Terminal times can be obtained from data on average walking distances which are generally available from parking surveys. It can also be estimated by personal judgment. An estimate of this important measure is considered better than omitting it completely. Estimates of future spatial separation between zones can be made if the location and geometrics of the future system are known. Terminal times can be estimated for the future using estimating procedures similar to those used for the present period.

3. Traveltime factors.--Traveltime factors[1/] (F_{ij}) are measures of the impedance to interzonal travel due to the spatial separation between zones. They measure the probability of trip making at each one-minute increment of traveltime; thus, there is one traveltime factor for each one minute of traveltime in the area. Mathematically, this factor is inversely proportional to the traveltime between zones raised to some power which may vary depending on the traveltime increment and the purpose of the trip.

To obtain traveltime factors for the present period, it is currently necessary to go through a process of trial and adjustment, mainly because the specific mathematical function which these values follow has not as yet been satisfactorily determined. The present period traveltime factors are usually assumed to remain the same for the future. The validity of this assumption has never been definitely proven, but evidence from some studies (10) (11) indicate that there is some basis for making the assumption.

1/ Traveltime factors are sometimes referred to as "friction factors." Table V-2 illustrates a set of traveltime factors for several trip purposes.

4. Zone-to-zone adjustment factors.--The remaining input to the gravity model formula is concerned with defined social and economic linkages which affect travel patterns; these are represented by the zone-to-zone adjustment factor (K_{ij}). These factors are not usually necessary. To date these factors have not been completely identified or quantified but there is some indication that they are related to such factors as income and occupation or to a unique relationship between the use of land and trip making which may exist in a particular part of the urban area (10) (12). The development of zone-to-zone adjustment factors is explained in chapter V.

C. Data Needed to Determine Parameters

Origin-destination survey.--All the factual data referred to in chapter II must be available in sufficient detail and with the proper statistical stability to provide reliable estimates for the gravity model parameters. Origin and destination survey data must be available in sufficient amounts to provide information on zonal trip production and trip attraction values by trip purpose category. In addition, the origin-destination survey data, particularly the zone-to-zone movements, are needed in the trial and adjustment procedure for determining traveltime factors. The origin-destination survey zone-to-zone movements are also used in determining the need for, and the values of, zone-to-zone adjustment factors (K_{ij}). Finally, these same zone-to-zone movements provide essential information for analytical and statistical tests of the ability of the calibrated gravity model to simulate current trip distribution patterns. In these respects, the standard home interview survey (3), if properly conducted, yields the most complete and accurate data for calibrating a gravity model.

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CHAPTER V - CALIBRATING THE GRAVITY MODEL	September 1965

A. General

There are several phases involved in calibrating a gravity model trip distribution formula for an urban area.

1. Phase one is concerned with processing basic data on the area's travel patterns and transportation facilities into a more usable form for analysis purposes.

a. For the travel pattern inventory, this involves selecting the basic travel data for which models will be calibrated.

b. For the transportation facility inventory, this involves determining the spatial separation between the zones.

2. Phase two utilizes the previously processed trip survey cards to obtain productions and attractions for the required combinations of trip purpose and travel mode category.

3. Phase three is concerned with the calibration process to be followed for each of the gravity models.

4. Phase four is concerned with balancing the attractions for the final calibration of the gravity model.

5. Phase five is concerned with the development of adjustment factors which may be required to properly calibrate the models to accurately simulate present travel patterns. The adjustments may be required for the following conditions:

a. Geographical bias, as caused by topographical barriers such as rivers, is removed by adjustment of the minimum path traveltimes in the network.

b. Geographical bias, as caused by defined social or economic conditions, is removed by zone-to-zone adjustment factors (K_{ij}).

The remainder of this chapter discusses the specific details involved in the five phases of the gravity model calibration process.

B. Phase One - Processing Basic Data

1. Selecting trip records.--The first step in the calibration of gravity models is to select the basic data. These data are the same trip cards which were used in building trip tables for the O-D assignment in chapter III, except that they are combined differently in order to obtain productions and attractions.

2. Determining interzonal driving time.--Just as the results of the travel pattern inventories had to be prepared for further analysis, so must the results of the transportation facilities inventory. The reprocessing of these data is necessary for the development of skim trees (interzonal driving times) for all zones and external stations. The skim trees are the driving times from one zone to all other zones. This information is one of the parameters required for the gravity model. Skim trees are also part of the data required to obtain an O-D trip length frequency distribution which is later used in the trial and adjustment process for developing traveltime factors.

The skim trees are obtained with the edit and tree builder, assignment 1 program. A separate run of the program with the final link data cards and the correct switch settings will produce the skim trees (type 24 cards). However, it should be noted that the skim trees do not contain any measure of driving time for intrazonal trips - trips which do not leave a particular zone. This time is called intrazonal driving time and must be derived separately. The values for these intrazonal times will be added to the skim trees with the update skim trees program. They are also needed for the gravity model, as it requires some value of intrazonal driving time in order to distribute the intrazonal trips.

3. Determining intrazonal driving time.--The intrazonal driving time is defined as the average driving time for a trip which begins and ends in the same zone without crossing the zone boundary. For example, one way of determining intrazonal time is by calculating the average driving time from the zone centroid to all points on the zone boundary.

Previous studies have indicated that intrazonal driving time greater than 4 minutes is probably excessive, except for external stations. At external stations, intrazonal trips are impossible, yet the gravity model may produce this type of trip. Intrazonal trips at external stations can be prohibited in the gravity model trip distribution by the use of an intrazonal driving time which is higher than any traveltime in the study area.

4. Determining the traveltimes.--Up to this point we have obtained the interzonal and intrazonal driving times. But, it has been determined that spatial separation between zones is more realistically measured by traveltime, which is the sum of the over-the-road driving time between zones and the terminal times within both the origin and the destination

zones. Consequently, it is necessary to develop a measure of terminal time for each zone in the study area. The terminal times must be included with the driving times in obtaining the O-D trip length frequency distribution and in distributing trips with the gravity model program.

Terminal time may consist of the following:

a. The time spent in cruising for a parking place at a nonhome destination end of a trip

b. The time spent in walking from a parking place to an actual destination of a trip, be it an office, store, recreation facility, or home

c. The time spent in walking from a trip origin, be it the home, an office, or other such origin, to the parking lot

d. The time spent in getting from the parking lot to the street system at the origin end of the trip

The factors affecting terminal time are related to the amount of congestion in a zone. There are no precise methods for estimating terminal times, but several methods have been employed by various transportation studies. These methods have ranged from 1) the systematic estimation of a terminal time for each zone based upon a formula using data for each zone, to 2) the subjective allocation of a terminal time based upon data from studies such as a parking survey or, 3) the subjective allocation of terminal times based upon a good knowledge of the study area.

Estimates based on judgment may be more suited for determining terminal times in smaller urban areas than terminal times based upon some formula. One method which has been used consists of approximating the terminal times through the use of time rings, and assigning the terminal time values according to the ring in which the zone happens to fall. The downtown area would usually fall into the high time ring, the intermediate areas could fall into lower value time rings, and the remainder of the city could be assigned the minimum terminal time.

5. Updating the skim trees.--Once the intrazonal and terminal times have been determined for each zone, they must be coded in the card type 31 format for use with both the update skim trees program and the gravity model program.

Once the type 31 cards have been punched and checked, the update skim trees program can be run according to the instructions in the program description. The output of this program are the updated skim tree cards, type 24, containing intrazonal and interzonal traveltimes. This deck should be marked so that it will not be confused with the skim trees containing interzonal driving times only. Both decks are card type 24, except that the updated skim trees have a "1" identification punch in card column 8.

C. Phase Two - Obtaining Productions and Attractions

The same trip and zone equivalent cards that were used to build trip tables are used to obtain gravity model productions and attractions with the trip end summary program; however, all the purposes must be sorted together with the origin zone as the major sort and destination zone as the minor sort. The parameter card formats and operating instructions are found in the program description.

The output of the trip end summary program consists of the type 30 cards for each of the three trip purposes. Total purpose type 30 cards are punched as purpose 04. Work trips are purpose 01, nonwork trips are purpose 02, and nonhome based trips are purpose 03.

The type 30 cards for each purpose, except purpose 04, are used for the gravity model program runs after the development of the remaining input data.

D. Phase Three - Calibrating the Gravity Model

1. Developing O-D trip length frequency distributions.--The O-D trip length frequency distributions are now obtained for each general purpose and travel mode as the first step in the gravity model calibration process. These distributions by one-minute traveltime increments are required in the trial and adjustment procedure for developing the traveltime factors. All the information necessary for obtaining the distributions is available from previous operations. Each deck of trip tables with the updated skim trees is used for a separate run of the trip length frequency program. The program works as follows: The total number of trips in each one-minute traveltime increment is accumulated by combining the number of trips between each zone pair with the minimum path traveltime between the two zones. The percentage of total trips and the minutes of travel are then calculated for each time increment. The output of the trip length frequency program are the type 37 cards. This card format is the same as the gravity model card type 35, except for the card number.

After the trip length frequency output (type 37 cards) has been listed, the percentages are plotted against their respective traveltime increments on rectangular coordinate paper. An example of a trip length frequency curve is shown in figure V-1. This curve is then used as a base for the trial and adjustment process for determining the effect of traveltime on trip interchange, F_{ij}. In addition, it is desirable to compute the total number of trips and the total minutes of travel for each trip purpose and travel mode. The number of minutes of travel is the area under the trip length frequency curve as shown in figure V-1.

a. The trip length frequency program has provided the number of trips and vehicle-minutes for each one-minute traveltime increment.

b. The vehicle-minutes of travel for each time increment are added together to obtain the total quantity of trip making for each

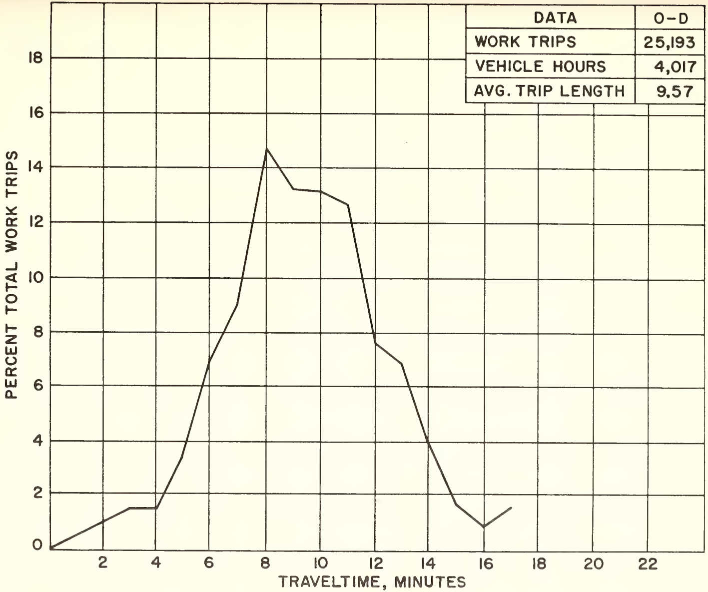

Figure V-1.--O-D trip length frequency distribution, Sioux Falls, S.D., 1956.

trip purpose and travel mode category. This information is also used as a check in the trial and adjustment procedure for determining the effect of traveltime on trip interchange.

Next, the mean trip length for each general trip purpose and travel mode category is obtained by dividing the vehicle-minutes of travel by the total number of trips in each of the respective categories. These data are also used in the determination of traveltime factors (F_{ij}) as will be discussed in following sections of this volume.

2. Selecting initial traveltime factors.--At the present time, a specific mathematical equation or function which can adequately express the effect of spatial separation on zonal trip interchange is not available. A single exponential function of traveltime has been proven to be inadequate. Other functions are currently being tried and evaluated but to date have not proven satisfactory. Consequently, it is necessary to go through a trial and adjustment procedure (or a calibration, as it is called) to arrive at a quantitative measure of this effect. This quantitative measure is called a traveltime factor and its use in the gravity model formula is shown in chapter IV of this volume.

In the preceding discussions, all of the basic inputs to the gravity model formula, with the exception of traveltime factors (F_{ij}), have been developed. Zonal trip production (P_i) and trip attraction (A_j) values for each trip purpose and travel mode category have been obtained with the trip end summary program. In addition, minimum path traveltimes (t_{ij}) between all zones have been developed with the update skim trees program. It is the purpose of this section to discuss how the traveltime factors are developed.

The initial set of traveltime factors for each trip purpose and travel mode category can be determined in at least two ways. First, one can assume that each traveltime factor has a value of one, or in other words, that traveltime has no effect on trip interchange. It is known, however, that this is never the case. Second, a set of traveltime factors can be borrowed from some other city of similar size.

The results of one of these methods for determining traveltime factors are used in the gravity model formula, together with the skim trees, intrazonal and terminal times, and the zonal trip production and trip attraction values.

3. Iteration procedure to get final traveltime factors.--With the initial set of traveltime factors determined for each trip purpose and travel mode category it is now possible to calculate trip interchanges using the gravity model formula. This is done using the program which is described in chapter XVIII of this volume.

Input to the gravity model consists of the following items for each trip purpose and travel mode category:

a. Zonal trip production and trip attraction values as obtained from the trip end summary program

b. Minimum path driving times (skim trees) between all zones as obtained from the traffic assignment 1 program (These are not the updated skim trees.)

c. The intrazonal driving times and terminal times

d. Initial traveltime factors for each one-minute increment of traveltime

e. Zone-to-zone adjustment factors (K_{ij}) if not equal to 1.00 (These adjustment factors are discussed in a later section.)

Output from this program consists of the following items:

a. A table of zone-to-zone movements as estimated by the gravity model formula, if the option is specified (This table is a card type 03 that is in the same format as the trip table obtained from the survey data using the trip table builder program, except that the trips are in a nondirectional production to attraction format.)

b. Two sets of type 30 cards (The first set contains the gravity model attractions (type 30a). The second set of type 30 cards (type 30b) contains the adjusted gravity model attractions. The type 30b cards are used for balancing attractions in the final calibration of the model. The attractions are adjusted in the following manner: The attractions used as input data are squared and then they are divided by the output model attractions to obtain the adjusted attractions.)

c. A trip length frequency distribution, by one-minute traveltime intervals, of trip interchanges estimated by the gravity model formula (These distributions contain intrazonal trips.)

The trip length frequency distributions are the output most directly used at this point. In addition to these data, the vehicle hours of travel are also obtained. The percentage of trips, for each trip purpose and travel mode category are plotted, on rectangular coordinate paper, versus their respective traveltime increments. For convenience, these curves should be plotted on the same sheet as the trip length frequency distributions obtained from the O-D travel pattern inventories. Figure V-2 shows the O-D and the gravity model trip length frequency curves for a given set of information. Also shown are the vehicle hours of travel and the mean trip length.

The above information is sufficient to begin the trial and adjustment procedure for determining the "best" set of traveltime factors for each trip purpose and travel mode category. Comparisons between the actual and the estimated distributions indicate the degree to which the traveltime factors were correctly chosen.

A comparison is made, for each trip purpose and travel mode category, between the actual and the estimated trip length frequency curves in regard to the

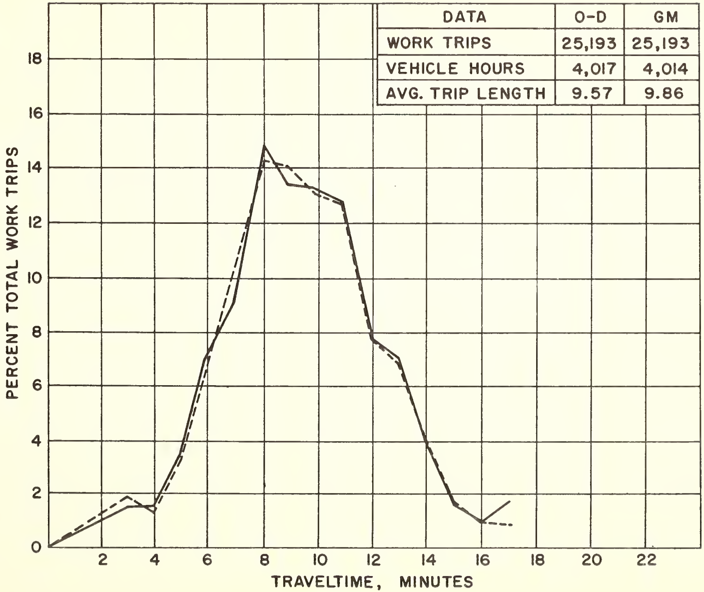

Figure V-2.--O-D and gravity model trip length frequency distributions, Sioux Falls, South Dakota, 1956.

following criteria:

a. Both curves should be relatively close to one another when visually inspected.

b. The difference between mean trip lengths for both sets of data should be within $\pm$ 3 percent.

If the comparisons do not meet these criteria, then adjustments are made to the assumed set of traveltime factors for each trip purpose and travel mode category. To make this adjustment, the standard form shown in table V-1 is used for recording the information. The actual adjustment is made for each traveltime increment by multiplying the traveltime factor used for each increment by the ratio of the percentage of surveyed trips to the percentage of estimated trips for the respective time increments. Mathematically:

$$F_{adj.} = F_{used} \times \frac{OD\%}{GM\%}$$

where: $F_{adj.}$ = Traveltime factor to be used in plotting for the next calibration

F_{used} = Traveltime factor used in the gravity model run being analyzed

OD% = Percentage of origin-destination survey trips of the appropriate length

GM% = Percentage of gravity model trips of the appropriate length, from the run being analyzed.

This calculation results in an adjusted traveltime factor for each one-minute increment of traveltime for each trip purpose and travel mode. Examples of these calculations are also shown in table V-1.

The adjusted traveltime factors for each one-minute traveltime increment are then plotted against their respective traveltime increments on log-log graph paper as shown in figure V-3. This is done for each trip purpose and travel mode. A "line of best fit" is hand fitted to the distribution of points, as shown in figure V-3. This hand fitted line should be as smooth and as straight as possible, keeping in mind that it should also approximate the distribution of points. The line shown in figure V-3 meets these criteria satisfactorily. It is important to keep these lines as smooth and as straight as possible for the following reasons:

a. People usually do not evaluate time close enough so that exact point traveltime factors may be used.

b. By smoothing and straightening the curve on a log-log plot, we can approximate a mathematical expression of a constant exponent.

Table V-1.--Traveltime factor work sheet

PURPOSE Home Based Work Trips

YOUR CITY AREA TRANSPORTATION STUDY

Travel-time	% Trips Actual	F Factor #1	% Trips Est. #1	Adj. F Factor	F Factor #2	% Trips Est. #2	Adj. F Factor
1	0.00	00	0.00	00	00		
2	0.00	00	0.00	00	00		
3	6.09	142	4.88	177	185		
4	10.28	132	10.32	131	150		
5	12.61	122	13.49	114	125		
6	12.57	112	13.62	103	110		
7	13.91	102	13.26	107	100		
8	11.22	92	11.26	92	85		
9	10.91	82	11.42	78	79		
10	4.20	72	6.04	50	67		
11	4.40	62	5.33	51	61		
12	3.98	52	3.52	59	57		
13	1.53	42	1.56	41	50		
14	1.34	32	1.09	39	48		
15	1.70	22	0.74	51	45		
16	0.04	12	0.08	06	10		
17	0.01	00	0.04	00	02		

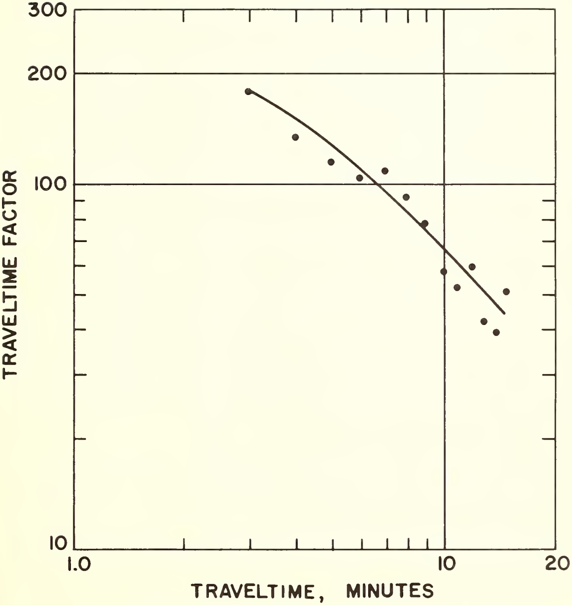

Figure V-3.--Log-log plot and curve of best fit for traveltime versus traveltime factor.

Comparisons between these expressions for different urban areas can then be made more meaningful.

Once this line has been drawn, a curve similar to figure V-3 can be entered and a new set of traveltime factors selected. For example, the new traveltime factor for 9 minutes would be 75; for 10 minutes it would be 70; for 20 minutes it would be 32 and so forth.

These new sets of traveltime factors are then used in a repeat run of the gravity model program. Zonal trip production (P_i) and trip attraction (A_j) values and the minimum path driving times (t_{ij}) between all zones remain as previously described for use in the first run of this program. This second run results in a second estimate of trip interchanges, and a new trip length frequency curve for each trip purpose and travel mode category. The trip length frequency curves for the second run are then compared with those resulting from the origin-destination survey and if this comparison does not meet the criteria another new set of traveltime factors is developed as previously described. The gravity model program is then rerun and the process repeated until the criteria are met. Operationally this trial and adjustment procedure for determining traveltime factors should take about three runs, assuming that reasonable first approximations of the final traveltime factors were used.

Examples of traveltime factors are shown in table V-2. The factors for work trips are the same as the example which was completed in table V-1.

E. Phase Four - Balancing Attractions for the Final Calibration

When the mean trip length and the trip length frequency curves meet the established criteria, the model attractions should be balanced. The reason for balancing attractions is obvious if the gravity model formula of chapter IV is reviewed. There is no assurance that the trips attracted to each zone by the model will equal those trips shown as attracted to each zone as summarized by the trip end summary program. It is desirable to have the attraction figures equal on a zonal basis before the zone-to-zone interchanges are analyzed further.

Balancing attractions is accomplished by using the type 30b gravity model cards in place of the type 30 trip-end summary cards and rerunning the gravity model program. Operationally, it takes only one run to balance the attractions. However, the trip length frequency distribution and the mean trip length must still check according to the same criteria as was used in determining the final calibration. In some cases, it will be necessary to make another calibration in order to properly balance the model attractions.

F. Phase Five - Adjustment Factors for the Gravity Model

1. Topographical barriers.--Some of the gravity model studies conducted to date have shown that topographical barriers, such as mountains, rivers, and large open spaces, may cause some bias in the gravity model trip interchange estimates. For example, a recent study in Washington, D.C., (12) indicated that the Potomac River had some influence on trip distribution patterns. A

Table V-2.--Final traveltime factors, Sioux Falls, South Dakota, 1956 data

Traveltime	Trip Purpose		
	Work	Nonwork	Nonhome based
3	185	220	210
4	150	160	120
5	125	130	100
6	110	090	080
7	100	085	070
8	085	070	060
9	079	060	055
10	067	050	044
11	061	039	038
12	057	035	032
13	050	027	030
14	048	025	026
15	045	021	023
16	010	016	014
17	002	000	005
18	000	000	000

study in New Orleans, Louisiana, (13) indicated similar findings. A study in Hartford, Connecticut (14), indicated that the toll bridges crossing the Connecticut River also affected travel patterns.

The nature of the influence of such topographical barriers is not precisely known. All of the above-mentioned studies have analyzed the apparent reasons why these barriers have influenced travel patterns in their own unique situation. In Washington, D.C., (12) it was attributed to the fact that off-peak hour traveltimes did not correctly indicate the amount of congestion which was present on those bridges crossing the Potomac River. An analysis of congestion patterns in the region indicated that there was more congestion in the area of the Potomac River, than anywhere else in the region. From this analysis, it was reasoned that a more realistic measure of the traveltime on these bridges was required. In the Hartford study (14) it was attributed to the fact that tolls are collected on several bridges crossing the Connecticut River. Since travel costs can also influence travel patterns, it was concluded that this cost barrier should be reflected by increased traveltimes on those bridges on which tolls were collected. In New Orleans (13), the Mississippi River separates several parishes. Many persons cross this river by ferry boat, as well as over the bridges. It was concluded that traveltimes on these bridges should be increased to account for the effect of the long traveltimes necessary to cross the river by ferry boat.

In each of the above cases, it can be noted that the effects of topographical barriers were incorporated in the gravity model by inserting time penalties (or impedances) on portions of the transportation network. In each case it appears that the need for these penalties is influenced by our present lack of knowledge as to a precise measure of spatial separation between zones.

It is important to point out that when time penalties are imposed on portions of the transportation network, these penalties must be taken into account in the frequency distribution of trips observed during the survey of travel patterns. This can be done by first changing the network and obtaining new skim trees. Then, the trip interchanges, for each trip purpose and travel mode, are reprocessed to obtain a new trip length frequency distribution.

The revised trip length frequency distributions and mean trip lengths are then used as a base against which any subsequent gravity model calibrations (also reflecting the time impedance) are compared.

2. Developing zone-to-zone adjustment factors.--It has been pointed out that there can be factors, other than the initial input to the model which may affect the patterns of urban travel. Travel patterns may also be influenced by various social and economic conditions which, to date, have not been completely identified or quantified. The effect of these factors may be accounted for in the gravity model formula by the use of zone-to-zone adjustment factors (K_{ij}).

In the larger urban areas where there are many types of major employment and shopping, and recreation centers of different types, these adjustments may be significant. However, in the smaller urban areas, one will usually find it unnecessary to use K_{ij} factors.

Because of the limited research on this particular point, the underlying reasons behind the K_{ij} factors are not completely understood. However, several studies1/ have indicated that the following may influence our ability to identify the real causes for the need to incorporate zone-to-zone adjustment factors into the gravity model formula:

a. The trip purpose stratifications used today may not be precise enough to account for all of the basic differences in travel patterns. Home based work trips provide an example. Most studies deal with these trips in total as one trip purpose category (i.e., total work trips). This has an important effect on the distribution of trips because total work trips cannot be distributed according to the type of employment opportunities that may be available in the urban area. For example, assume that all work trips produced by a particular zone are made by industrial workers. When distributing these trips with the gravity model, or any other travel model, the largest proportion of these trips would be sent to the closest zones with large employment centers, regardless of the type of employment that is available. This means that many of these industrial workers may be sent to large offices and commercial establishments mainly because of their proximity to the residences of these workers. However, if total work trips were to be further stratified according to white collar and blue collar workers this deficiency might be substantially corrected. However, such a stratification may create problems in forecasting, since it would be more difficult to forecast the place of residence and the employment opportunities for blue collar and white collar workers than it would be to forecast these variables for all workers.

Similar problems may also exist in the other trip purpose categories because of insufficient stratification. Suspected items of this nature complicate the problem of isolating the deviations that can be legitimately attributed to phenomena associated with a K_{ij} factor.

b. In present practice, a set of traveltime factors is developed for each trip purpose and travel mode category. Since trips between all zones are used in developing these factors, they represent the average areawide effect of traveltime on trip interchange. However, there is some evidence which tends to show that traveltime factors vary by zone depending on the characteristics of the people who live in each zone and on the distribution of land use activities immediately adjacent to these zones.

c. There is some evidence that factors such as income and occupation may influence the need for zone-to-zone adjustment. In Washington, D.C. for example, it was observed that low income workers were not as likely to be employed in the central business district as were higher income workers. This observation was made by direct comparison of zonal interchanges estimated by the gravity model formula and those from the origin-destination survey.

1/ See, for example, references (12), (10) and (14).

Regardless of the reason for zone-to-zone adjustment factors, the need may possibly exist for incorporating them into the gravity model formula. Even with these many limitations on the understanding of the K_{ij} factor, tests to determine the extent of the required adjustments and procedures for incorporating them into the model have been devised and used in several studies.[2/] These procedures require an analysis of the differences between the trip interchanges calculated in the final run of the gravity model program and those measured in the travel survey.

Limited experience has shown that it is for the large traffic generators that the gravity model trip interchanges must be adjusted. For example work trips between all zones and the central business district of an urban area may require adjustment. Occasionally trips between one city of an urban complex and another city within the same complex might require adjustment. Consequently, the procedure used to develop adjustment factors is to compare the trip interchanges between large traffic generators as estimated by the gravity model with those developed from an origin-destination survey. These comparisons are usually made graphically for work trips and then for the other trip purposes, if necessary. This is usually accomplished by plotting the pertinent movements. A district map is used in this analysis. Sector lines are drawn to denote major traffic drainage areas. A fictitious radial transportation route is assumed to serve each of these sectors. The movements between each district (by major trip purpose category) and the central business district are then manually "assigned" to the radial facility within the sector in which the district is located. These volumes are then accumulated to the central business district. Using this procedure, systematic differences which reflect the need for K_{ij} factors can be located. Further information can be found in reference (2).

Once the zone-to-zone adjustment factors (K_{ij}) have been determined, it is necessary to incorporate these factors into the gravity model calculations. To do this, the gravity model program is rerun using the same input data except that zone-to-zone adjustment factors are used.

The trip length frequency of this revised trip distribution pattern must then be checked against the origin-destination survey distribution to verify its correctness. In most cases, there will be no need to make further adjustments.

2/ See, for example, references (12), (13), and (14).

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

CHAPTER VI - ASSIGNING AND TESTING THE GRAVITY MODEL TRIP DISTRIBUTION	September 1965

A. General

This chapter is concerned with developing final measures of the overall accuracy of the gravity model distribution by assigning the model trips to the transportation network. The results of statistical tests developed with the trip comparison program and graphical tests made manually are used in this analysis.

B. Assigning the Gravity Model Trips to the Present Network

After the calibrated gravity model trip tables (type 03 cards) have been obtained, they are assigned to the present network in the same manner as the O-D trip tables (see chapter III).

The nondirectional assignment (type 05 cards for the gravity model trips) can be compared directly with the O-D type 05 cards from the assignment 2 program. The two type 05 card decks are used as input to the trip comparison program.

C. Statistical Tests

The statistical tests are generally applied only after the gravity model has been calibrated to a trip distribution pattern obtained from an origin-destination survey. The procedure is to compare the final gravity model trip interchanges with the trip interchanges derived from the origin-destination survey for each of the major trip purpose and travel mode categories. The trip comparison program is used to do this. Specific details on this program can be found in the program description.

This program accepts the two type 05 card decks of trip information as input, one containing the survey, and the other the corresponding gravity model estimates. These data will be the nondirectional link volumes obtained by assigning the final zonal trip tables obtained from the trip table builder and gravity model programs.

The trip comparison program initially produces a table of differences between the gravity model link volumes and those from the origin-destination survey as shown in table VI-1. Next, it separates the movements into a maximum of 15 categories depending on the survey volume. For each of these

Table VI-1.--Trip comparison program output, table 1

SIOUX FALLS, S.D. WORK TRIPS (LINK VOLUMES) O.D. VS G.M.
TABLE 1 - COMPARISON OF LINK VOLUMES

ANODE	BNODE	O.D. VOLUME	G.M. VOLUME	DIFFERENCE
1	264	10	38	28
1	266	40	14	-26
1	267	78	67	-11
1	277	0	5	5
2	231	10	30	20
2	237	0	0	0
2	238	80	72	-8
2	250	10	0	-10
3	228	30	33	3
3	235	40	9	-31
3	236	0	33	33
3	247	20	16	-4
4	189	29	2	-27
4	198	20	28	8
4	199	20	26	6
4	206	0	7	7
5	225	0	0	0
5	233	80	46	-34
5	234	0	40	40
5	244	0	0	0
6	275	92	77	-15
6	284	0	6	6
6	286	0	3	3
6	288	0	0	0
7	311	80	85	5
7	313	0	0	0
7	314	40	15	-25
8	289	0	0	0
9	192	0	7	7
9	200	40	31	-9
10	170	0	13	13
10	180	0	33	33
10	181	110	61	-49
11	182	78	78	0
12	159	68	56	-12
12	175	0	6	6
13	138	0	0	0
13	140	20	10	-10
13	141	0	4	4
13	158	0	3	3

15 volume groups, the differences between each of the origin-destination survey and the gravity model movements may be tabulated according to magnitude into 15 difference groups. For each volume group the sum of the squares of the differences, the mean difference, the root-mean-square error, the number of O-D survey trips, the percent root-mean-square error, and the number of gravity model trips are given. This information is punched out in a form ready for listing as shown in table VI-2. Information such as that shown in table VI-2 is used in the statistical analysis while that shown in table VI-1 is generally used for analytical purposes.

Table VI-2 shows the frequency of occurrence of various levels of differences between the gravity model and the origin-destination survey movements within the 350-399 volume group. It also shows the sum of these differences, the sum of their squares, the mean difference, the root-mean-square error with its percent, and the total trips from both sources, within this volume group. It can be seen that a total of six movements falls into this category. The most serious deviation between the gravity model and the origin-destination survey movements is minus 75. The remaining information is easily understood.

The RMS error has associated with it the two-thirds confidence level. This means that for this volume group it may be stated that two-thirds of the time the difference between the origin-destination survey and the gravity model movements is between $\pm$ 43 trips. The relative error for the volume group is approximately $\pm$ 11.5 percent. This relative error, however, assumes that there is no error in the information against which the gravity model results are being compared. Of course, this is not true, since all sampling procedures contain errors due both to reporting problems and to sampling techniques. Consequently, the previously calculated relative error does not mean that the gravity model error is $\pm$ 11.5 percent; as the model was compared with the origin-destination survey results, which, being the product of a sample survey, have an inherent error related to sample size.

The errors related to sample size can be estimated using the results of some past work by the Bureau of Public Roads. Figure VI-1 shows a series of curves which illustrate the approximate RMS error which can be associated with different volume groups for different sample sizes. For the data shown in table VI-2, the origin-destination survey sample size was 12.5 percent. From the curves in figure VI-1, it can be seen that the percent RMS error associated with this sample size for a mean volume of 375 trips is about 27.0 percent.

This means that for volumes of 375 trips, a 12.5 percent origin-destination survey sample will give an estimate of total trips which 2/3 of time is within $\pm$ 27 percent of the value that would have been obtained from a 100 percent sample, if such a sample were possible.

D. Analytical Tests

Generally, the analytical tests to be discussed below are applied only when the gravity model has been calibrated using a trip distribution pattern

Table VI-2.--Trip comparison program output, table 2

TABLE 2 - FREQUENCY DISTRIBUTION AND ANALYSIS OF DIFFERENCES

VOLUME GROUP 350 TO 399

DIFFERENCE			FREQUENCY	SUM OF DIFF.
-70	TO	-79	1	75
-50	TO	-59	1	57
-30	TO	-39	1	30
-20	TO	-29	1	28
-10	TO	-19	1	19
10	TO	19	1	15
TOTALS			6	-194

SUM OF SQUARES	11144.	MEAN DIFFERENCE	-32
RMS ERROR	43.09	PER CENT RMS ERROR	11.54
TOTAL O.D. TRIPS	2240.	TOTAL G.M. TRIPS	2046.

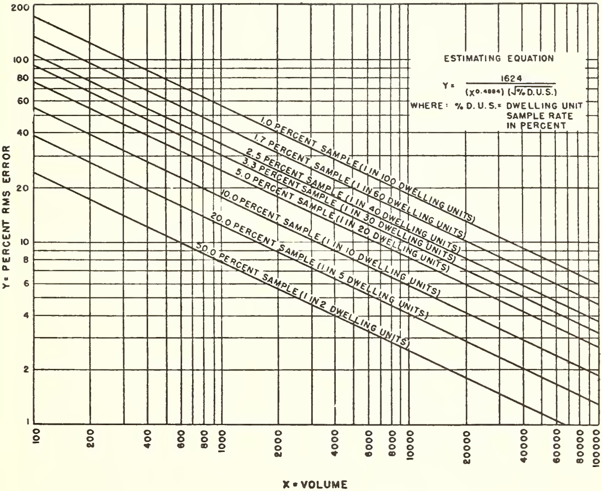

Figure VI-1. Relation of percent root-mean-square error and volume for various dwelling-unit sample rates.

obtained from an origin-destination survey. The analytical tests need little explanation because the procedure for conducting them is almost identical to the method used to locate the need for zone-to-zone adjustment factors (K_{ij}). This has previously been discussed in chapter V.

However, it is important to discuss three points in respect to the use of analytical tests. First, such tests are very necessary. The statistical tests give an excellent picture of the overall accuracy of the gravity model in reproducing travel, but they do not point out geographical bias. The sector type of analysis described in chapter V, therefore, should always be made in addition to the statistical tests, particularly, since each sector, or traffic drainage corridor, is generally served by at least one major radial route, and any geographically biased error could have serious design consequences.

Secondly, the use of the results of these analytical tests are invaluable in explaining the accuracy of the gravity model to policy makers or citizen groups who may be interested in the forecasting techniques used for arriving at transportation facility proposals. Statistical tests have only minor application when explaining the forecasting techniques to such groups.

Finally, the output of the trip comparison program can be used for a graphical analysis. The differences between the gravity model and the origin-destination survey link volumes are plotted. The plot will give an indication of the error in the nondirectional assignment. This output cannot be used as source data for design purposes because the movements are between production and attraction zones instead of between origin and destination zones. The conversion of these movements to origin-destination movements is covered in the following section.

E. Converting the Gravity Model Results to Directional Movements

Once the estimated gravity model trip interchanges have been shown to reproduce the travel patterns surveyed by the field inventories within an acceptable degree of accuracy, it is desirable to convert the gravity model results to directional movements between origin and destination zones. The gravity model results yield nondirectional movements between every zone of production and all zones of attraction, which when assigned to the transportation network produce nondirectional volumes. It is sometimes desirable to know directional volumes, but no provision has been made to convert the gravity model results to direct origin-destination movements using the IBM 1620 computer.

At the present time, any trip table conversion must be done manually and will require considerable time to complete an average size system. Consider the following example. Zone 1 produces 100 work trips daily which are attracted to zone 2. This is shown schematically in figure VI-2. Each of these trips leaves home in the morning and goes to the zone of attraction and returns directly home in the evening.

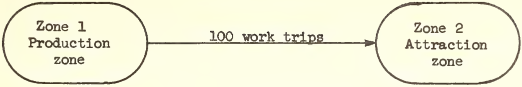

Figure VI-2.--Schematic gravity model trip interchange - case I.

The gravity model trip interchanges, converted to directional origin-destination movements could then be shown as in figure VI-3.

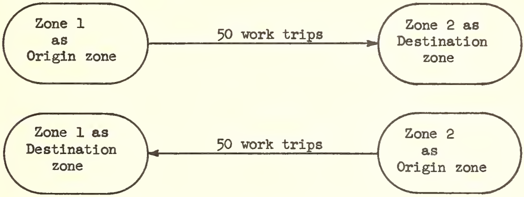

Figure VI-3.--Schematic origin to destination interchange - case I.

This is a rather simple case, but this is essentially how the trip conversion is done. If, however, not all of the workers returned directly home in the evening, but, instead, one-half of them stopped to shop on the way home, then only 75 work trips would have been produced by zone 1 and attracted to zone 2 as shown in figure VI-4.[1/] Of these, 50 or two-thirds of them, had the home as the origin zone and one third, or 25, originated at the work place.

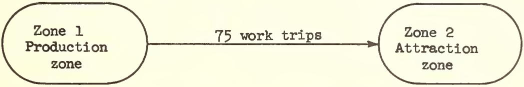

Figure VI-4.--Schematic gravity model trip interchange - case II.

The trip conversion process would then provide the movements as shown in figure VI-5.

1/ The remaining 25 trips would be shopping trips, produced by zone 2.

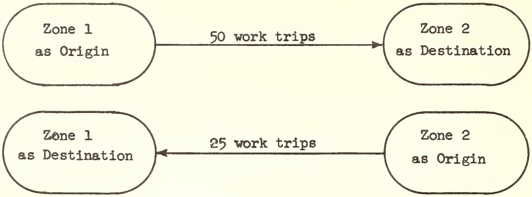

Figure VI-5.--Schematic origin to destination interchange - case II.

The trip conversion process uses trip interchanges in which trips are represented between production and attraction zones. The percentage of total trip production which are origins and the percentage which are destinations must be obtained for each trip purpose and travel mode category. In case I, above, 50 percent of the productions were origins and 50 percent were destinations. In case II, 67 percent of the productions were origins and 33 percent were destinations. These percentages must be either assumed or preferably arrived at by an analysis of the origin-destination survey data. This analysis is rather simple in theory but it requires a considerable amount of time. Essentially all of the trip cards for each trip purpose or travel mode category are sorted to determine how many of them are produced by all zones of origin and how many are produced by all zones of destination. The required percentages are then calculated directly. These percentages, which represent areawide averages, are then applied to each zone. Since for nonhome based trips, the zones of production and attraction are the same as the zones of origin and destination, respectively, the percentage split is always 50-50 for this purpose. Past experience has shown that a 50-50 percentage split will usually give good directional movements for the home based trip purposes also. The outputs from this process are directional movements between all origin and destination zones. This output can then be coded and assigned to the transportation network to obtain directional link volumes.

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CHAPTER VII - PREPARING THE PROPOSED STREET AND HIGHWAY NETWORK	September 1965

A. Coding the Network

The proposed street and highway nodes are coded into the network in the same manner as the existing system nodes. Chapter III describes the preparation of the existing network and allowance is made for the addition of a proposed system range of nodes.

In coding a proposed network for a diversion assignment, there are several items which should be noted. First, when coding future freeway nodes, the decision to make a diversion assignment must have been made during the coding of the existing network. If a diversion assignment is to be made, only the freeway nodes will have type 06, 07, and 08 cards punched for them. To obtain type 06 or 07 turning volume cards for any arterial intersection node, the node must be coded so that it is in the freeway node range but it must not be connected to any other node in the freeway node range. Second, when adding proposed arterial streets to the network, these street nodes should be added at the bottom of the arterial node range, otherwise the traffic will be assigned to the proposed arterial streets by the diversion curve, instead of by an all-or-nothing assignment. The example list of nodes for the existing and proposed system in table VII-1 can be compared with the existing system example list of nodes in table III-2.

Table VII-1.—Example list of nodes

Node group	Node numbers
Zone centroids	001 to 006
Station nodes	100 to 103
Arterial nodes	199 to 238
Proposed freeway	239 to 244

If an all-or-nothing assignment is made for a proposed network, only the freeway nodes will have type 06 and 07 turn volume cards punched for them. In order to obtain turning volumes for any other intersection, the node must be coded as was described above. There are no type 08 cards, diversion phase data, punched for this type of assignment.

B. Editing the Proposed System Network

Described in chapter III, section B, are the details of editing a network, except that the passes through the edit and tree builder must now be made in accordance with the instructions for editing a proposed network. These instructions are included in the program description for the assignment 1 program. The program control card for the edit passes through the program should be coded for punching only one tree while editing the proposed network. Punching only one tree will expedite the editing.

C. Building and Checking Proposed System Trees

After editing, the program control card is changed to build selected proposed system trees. The same general procedures that are described in chapter III are followed except that the assignment 1 program punches three types of cards (17, 18, and 19) in producing a proposed system tree. Instructions for the operation of the assignment 1 program are included in the program description.

In order to trace a proposed system tree path, the starting point is the destination node (which is a "B" node) in the type 19 card. The path is followed continually from each "B" node to its "back" node until a "back" node of zero, 000, is reached. The zero "back" node indicates that it is necessary to switch to the type 18 cards for this same home node number. The "B" node which had the zero "back" node is located as a "B" node on the type 18 cards. This indicates the node of the intermediate link, and the "back" node shown is used as the connecting node for the type 17 cards. The path is then traced from this "B" node on the type 17 cards. When the "back" node that is equal to the home node is reached, the proposed system tree has been traced. An example of this procedure is followed through for one tree in table VII-2. Sample proposed system minimum path trees are listed in table VII-3. Using the example trees for centroid ("A" node) 1 in table VII-3, one can follow the path from centroid 1 to centroid ("B" node) 6. This is the example shown in table VII-2.

Table VII-2.--Tracing a proposed system tree

Step no.	"B" node	Back node	Card type used
1	006	232	19
2	232	243	19
3	243	000	19
4	243	242	18
5	242	227	17
6	227	225	17
7	225	205	17
8	205	204	17
9	204	001 ("A" node)	17

Table VII-3.--Type 17, 18, 19 proposed system trees

Card type	City code	Home node ("A" node)	"B" node	Back node for link with the "B" node	Accumulated driving time, "B" to "A" node		"B" node	Back node for link with the "B" node	Accumulated driving time, "B" to "A" node		"B" node	Back node for link with the "B" node	Accumulated driving time, "B" to "A" node		"B" node	Back node for link with the "B" node	Accumulated driving time, "B" to "A" node	
17	020	001	001	000	000999	000000	002	208	000217	000000	003	221	000156	000000	004	234	000266	000000
17	020	001	005	216	000220	000000	006	232	000248	000000	100	217	000210	000000	101	240	000230	000000
17	020	001	102	241	000116	000000	103	227	000172	000000	199	230	000211	000000	200	204	000050	000000
17	020	001	201	001	000025	000000	202	201	000046	000000	203	202	000079	000000	204	001	000023	000000
17	020	001	205	204	000066	000000	206	202	000096	000000	207	203	000119	000000	208	209	000181	000000
17	020	001	209	206	000151	000000	210	205	000124	000000	211	210	000156	000000	212	207	000167	000000
17	020	001	213	210	000138	000000	214	213	000164	000000	215	212	000181	000000	216	217	000202	000000
17	020	001	217	222	000180	000000	218	217	000186	000000	219	220	000166	000000	220	221	000151	000000
17	020	001	221	224	000141	000000	222	203	000125	000000	223	200	000070	000000	224	203	000098	000000
17	020	001	225	205	000087	000000	226	224	000132	000000	227	225	000127	000000	228	226	000171	000000
17	020	001	229	227	000139	000000	230	229	000163	000000	231	228	000197	000000	232	199	000235	000000
17	020	001	233	231	000234	000000	234	233	000253	000000	235	236	000178	000000	236	224	000138	000000
17	020	001	237	236	000197	000000	238	237	000245	000000	239	000	000099	000000	240	216	000219	000000
17	020	001	241	223	000090	000000	242	227	000130	000000	243	233	000270	000000	244	233	000276	000000
18	020	001	239	240	000244	000000	240	241	000128	000000	241	242	000186	000000	242	241	000146	000000
18	020	001	243	242	000176	000000	244	243	000295	000000	000	000	000000	000000	000	000	000000	000000
19	020	001	001	000	000999	000000	002	208	000301	000000	003	221	000255	000000	004	234	000244	000000
19	020	001	005	216	000163	000000	006	232	000228	000000	100	217	000197	000000	101	240	000139	000000
19	020	001	102	241	000212	000000	103	227	000194	000000	199	230	000233	000000	200	223	000226	000000
19	020	001	201	200	000251	000000	202	201	000272	000000	203	222	000268	000000	204	205	000253	000000
19	020	001	205	225	000210	000000	206	205	000256	000000	207	212	000276	000000	208	209	000265	000000
19	020	001	209	211	000235	000000	210	242	000169	000000	211	210	000201	000000	212	211	000228	000000
19	020	001	213	210	000183	000000	214	213	000209	000000	215	214	000234	000000	216	240	000145	000000
19	020	001	217	216	000167	000000	218	217	000173	000000	219	218	000215	000000	220	219	000230	000000
19	020	001	221	220	000240	000000	222	217	000222	000000	223	241	000206	000000	224	221	000283	000000
19	020	001	225	227	000189	000000	226	228	000288	000000	227	242	000149	000000	228	212	000249	000000
19	020	001	229	227	000161	000000	230	229	000185	000000	231	233	000249	000000	232	243	000215	000000
19	020	001	233	243	000212	000000	234	233	000231	000000	235	220	000275	000000	236	235	000315	000000
19	020	001	237	228	000289	000000	238	234	000264	000000	239	240	000153	000000	240	000	000128	000000
19	020	001	241	000	000186	000000	242	000	000146	000000	243	000	000176	000000	244	243	000201	000000

It should be noted that the existing system tree from centroid 1 to 6 shown in table III-3 can also be followed on the type 17 cards shown in table VII-3.

Sample trees should also be plotted for the proposed system to examine the future network for coding errors and illogical routings. Each tree should be examined for faulty traces and the other errors which are described in chapter III.

When any errors in this proposed network have been corrected, a final run is made with the assignment 1 program to obtain the correct deck of type 02, link time, cards. An additional run of this program will now produce the skim trees, type 24 cards for the present and proposed system. The instructions for obtaining skim trees are in the assignment 1 program description. The proposed system skim trees have a "2" identification punch in column 80.

D. Alternate Proposed Systems

In order to test different proposed systems, each set of proposed nodes has to be added to the existing system separately. The same procedures as described in this chapter and in chapter III must be followed for each proposed set of arterial streets and freeways. The identification of each system must be maintained due to the large number of cards used with the IBM 1620 computer.

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CHAPTER VIII - DISTRIBUTION OF FUTURE TRIPS WITH THE GRAVITY MODEL	September 1965

A. General

At this point, a first approximation of a transportation system for the future year (generally, existing plus committed system) has been developed. Now, the calibrated gravity models developed from present data are used in forecasting future travel patterns for any desired year, alternative transportation system or land use pattern.

Zonal trip production and attraction values for each trip purpose and travel model category must be computed for the forecast year and the desired land use pattern. This is done utilizing mathematical expressions which define the relationship between present zonal trip production and attraction values and various land use and economic indicators. If desired, these equations can be revised to reflect any changes which may occur in trip generation characteristics for the future time period.

Traveltime factors, as developed from present data are used for the forecast year. Limited evidence (10) leads to the conclusion that this is a reasonable assumption to make.

Finally, if zone-to-zone adjustment factors (K_{ij}) were found necessary for the present time period, they may also be necessary in the future. These are developed for the future based on the curves or mathematical expressions which were used to develop or explain them for the present time period. For example, a recent study in Washington, D.C., developed zone-to-zone adjustment factors for all home based work trips to the central business district. These factors were then compared with the income level of the persons living in each zone and a curve was plotted to show the relationship between these two variables. In deriving zone-to-zone adjustment factors for Washington for the forecast year, transportation planners referred to this curve and estimated the factors for the future period, given an estimate of income.

Each of these items of data (i.e., zonal trip production and attraction values, traveltime factors, and zonal adjustment factors, if used) is then used as input to the gravity model program. The resulting nondirectional trip tables are then assigned to the existing plus committed transportation system. The results are analyzed to determine if the system can adequately satisfy the estimated travel demands. Based upon this analysis, the system is revised, recoded, and again described to the computer. Another system can also be

used in place of this one and the entire process repeated. In this way, a balanced transportation system which will satisfy the travel demands created by a particular land use pattern can be developed.

B. Future Trip Generation

Trip generation is the term commonly used to denote the relationships which exist between the urban environment and the urban travel demand. A study of trip generation does not provide us with all of the characteristics of travel, but simply the trips starting or ending in a particular zone. Trip generation is usually described in two categories - trip production and trip attraction. Trip production is the measurement of the number of trips produced by the residents of a household, neighborhood or an entire urban area, as determined from various socio-economic and location factors. Trip attraction is the number of trips attracted to a given area, as determined by such factors as area type and intensity of land use.

Considering trip production as phase one of a trip generation analysis, one finds that trip generation is related to the home and to the various socio-economic characteristics of the persons living there. The factors considered in this type of analysis include city size, residential density, cars owned by residents of the area, family income level, and the degree of decentralization of the area under consideration. Each of these, and probably many other factors, have important effects on the travel demand in the urban area.

In phase two of a trip generation analysis one attempts to analyze the trips by purpose with regard to the type of land use or other land use factor to which the trips are attracted. The trip attraction ends of the trips in a study area are usually allocated to each specific zone on the basis of the intensity of the land use or the intensity of the land use factor in that zone, as it relates to the total study area.

At this point some more discussion of both phases one and two is needed. What are presented here are not the only bases for the methods being used today for trip generation but are only some of the many characteristics of an urban area that influence the number of trips made each day. It is only in the results of future research that the proper applications of the most predominant and influential elements of trip making will provide an accurate means of forecasting future urban travel.

Phase one, or a trip production study, measures the number of trips produced by an area. The individual factors mentioned above are difficult to pinpoint due to the interaction between the factors. In general, trip making per unit of development or per person increases with car ownership, family income, and degree of decentralization. It also increases with decreasing residential density and city size. Past studies have shown that as tripmaking per person (or per unit of development) increases, there is a corresponding increase in the number of nonwork trips and in the number of trips made by car. These generalizations have importance and must be considered in planning facilities to meet future travel demands.

In order to work with the interrelationships between urban travel and land use, we must know, in addition, the purposes of the travel being produced. A past study of travel patterns in 50 separate cities (15) of all sizes and locations indicated that the relative distribution of major trip purposes is somewhat uniform in cities of all sizes. But, any one area in a city will exhibit a trip purpose breakdown which depends mainly upon the volume of trips per household.

Once the total trip production by purpose has been determined, it is necessary to estimate the modal split of these trips. In larger urban areas, approximately 75 percent of total travel is by automobile. As city size decreases, automobile usage increases. In the small urban areas nearly 95 percent of all travel is by automobile (16).

Each mode of travel offers certain advantages for various types of trips. The specific amount of travel in each zone, by mode, depends mostly upon the availability of alternate modes of transportation, family income, and residential density. Work trips, especially those oriented to the central business district, and school trips utilize transit more frequently than other trip purposes. Shopping, social-recreational, and other such types of trips generally are more dependent on the automobile. There is presently much research being done on modal split and much more detailed discussions on the methods used (models, regression, etc.) and new applications should be forthcoming in the near future.

The factors which help explain household trip production and mode of choice provide information on the kind of travel likely to occur in the future. It is expected that the average trips produced per household will increase as a result of growth in population and automobiles and declining average net residential density. Additional trip production may result as a consequence of rising family income--this may result in more social-recreational trips. The multiplying effects of the several factors must be accounted for in planning for future travel demand. The research being done on present day travel relationships will give us an improved basis of forecasting the future needs of urban areas.

Phase two of a trip generation analysis is the trip attraction study. Here the analysis attempts to quantify the relationships between trips and land use or land use factor for each trip purpose. Home based work travel has long been recognized to be the most important single part of total urban traffic. Past studies by the Bureau of Public Roads have shown that the number of work trips to a zone is highly correlated with the number of employees in that zone.

Some studies have attempted to relate work trips with industrial and manufacturing acreage, but have had less reliable results than those studies which obtained work trips based on the variation in employment.

Home based nonwork (particularly social-recreational) trips are increasing and are generally the second most important trip purpose category. These trips have been proportioned to zones in the past by population or dwelling unit ratios. Research has not been extensive enough to come up with definite recommendations as to what factors are best for determining trip

attractions but several factors have been used with varying degrees of success. Retail sales have been used as indices for shopping trips, but the unavailability of detailed retail sales figures usually prohibits their use. Variations in shopping trips have been correlated with parking space available, floor area, customer policies, and advertising.

Various land use factors have been used to allocate the attraction end of home based nonwork trips; retail sales in terms of square feet of floor area have been used with some success for shopping trips. School acreage and the number of persons of school age within each zone have been found to be indices to school attractions.

Nonhome based trips at both ends are associated with a combination of factors such as employment, retail sales and population. The relative effect of each of these factors has not yet been reliably determined.

The most efficient methods now in use for trip generation analyses make use of electronic computer programs. Some of the things to consider for a trip generation analysis could be as follows:

1. Availability of data

   a) Can it be obtained for the base year within reasonable economic limits?

   b) Can it be estimated for the design year?

   c) Does it offer some possibility of being significantly related to trip generation for a given purpose?

2. Most useful types of data

   a) Of the available data, what is the most useful?

   b) Can these data be related to trips by purpose?

3. Alternate forms of data arrangement

   a) Total trips and total measures of other items

   b) Trip rates or intensities

   c) Trips per unit or other measure

4. The method used for the analysis should be a function of the available data

5. Forecasts of data by zone

   a) Try alternate procedures.

   b) Check appropriate relationships for reasonableness.

6. Check the estimates from the method used. Look for inconsistencies such as unrealistic purpose split for certain zones based upon land use.

The results of a trip generation procedure should provide productions and attractions which can be used with the future gravity model.

C. The Gravity Model Distribution for a Proposed System

1. Productions and attractions.--Now that productions and attractions have been obtained, they must be put into the card format which is acceptable to the gravity model program. The type 30 card format is described in chapter V and is the same card type to be used for coding the productions and attractions of each trip purpose for the proposed system gravity model runs.

2. Skim trees.--The skim trees for the proposed system can now be obtained, if they were not obtained during the edit and tree building phase (see chapter VII).

3. Traveltimes and traveltime factors.--The next items to be considered before running the gravity model program are the traveltime factors. Investigation of the skim trees will show whether or not the driving times for the proposed system centroids are greater than the present system driving times. It is possible that the new system has incorporated a much larger area; this may affect the driving times and create more time increments than were used in the present system.

In order to obtain the traveltime factors for additional traveltime increments, one must obtain the future intrazonal driving times and terminal times for all zones; these are also needed for use with the gravity model. The methods for determining intrazonal and terminal times are discussed in chapter V. The traveltimes for the proposed system are obtained by updating the proposed system skim trees. The necessary card formats are described in chapter V. The intrazonal driving times and terminal times for the proposed system may be about the same or much different, depending on changes in the city.

After the skim trees are updated with the proposed intrazonal and terminal times, the traveltimes can be obtained from these updated type 24 cards. The final logarithmic curve of traveltime factors for the present system may now be used for obtaining the traveltime factors for additional time increments. The traveltime factor curve will be similar in form to the curve in figure V-3. The curve is extended, and the additional traveltime factors can be obtained from this curve.

4. Zone-to-zone adjustment factors.--Zone-to-zone adjustment factors, K_{ij} factors, are discussed in chapter V, section F. If K factors have been used for the gravity model distribution of present trips, they may be needed for the distribution of future trips. In order to obtain future factors, the variable or variables to which the K factors were related must be forecast to the future time period. Once the variables are obtained for the

future, the procedure for determining the future K factors would be the same as for the present gravity model. Ideally, an equation would be developed to reflect the relationship of the present trips to the variable or variables. The variable which was forecast for the future period could then be used to determine the future K factors.

When each of the previous items has been determined, the gravity model program can be run to determine the future travel patterns on the proposed street and highway system. The procedures in the program description would again be followed in order to obtain the nondirectional, type 03 cards, volumes for assignment and the type 35 trip length frequency cards for plotting.

The nondirectional volumes are now ready for assigning to the proposed system. To get directional volumes, the procedure in chapter VI, section E may be followed.

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CHAPTER IX - THE FRATAR TRIP DISTRIBUTION	September 1965

A. The Fratar Theory

The treatment of trips with both ends outside the cordon line was discussed in chapter II. The specific trip data to be used with the Fratar trip distribution procedure will depend on the decisions made concerning the treatment of these external trips. This procedure was presented by Thomas J. Fratar to the Highway Research Board in 1954.

The Fratar procedure, a growth factor method, is based on the premise that the distribution of trips from a zone is proportional to the present movements out of the zone modified by the growth factor of the zone to which the trips are attracted. The total volume of trips out of a zone is determined from the present trips out of the zone and the growth factor developed for the zone. The growth factor is obtained by dividing the estimated future trip ends for a zone by the present number of trip ends.

Mathematically, these statements can be expressed as follows:

1. Growth factor:

$$F_i = \frac{T_i}{t_i}$$

where: F_i = Growth factor for zone i

T_i = Future trip ends for zone i

t_i = Present trip ends for zone i

2. Future trip ends for zone i:

$$T_i = \sum_{j=1}^{n} (t_{ij} \cdot F_i)$$

where: t_{ij} = Present trips between zone i and zone j

The formula for the Fratar method is as follows:

$$T_{ij} = t_{ij} \cdot F_j \frac{\sum_{j=1}^{n} (t_{ij} \cdot F_i)}{\sum_{j=1}^{n} (t_{ij} \cdot F_j)}$$

where: F_j = Growth factor for zone j

T_{ij} = Future trips between zone i and zone j.

A second estimate of trips between zone i and zone j is made when zone j is considered as the zone of origin. The value for the future trips between the two zones is the mean of the two estimates.

After the zone-to-zone trips have been developed, the calculated trip ends in a particular zone will probably not agree with the desired future trip ends in the zone. Therefore new growth factors are calculated, and the formula is again applied. The growth factors used for the next trial, or approximation, are determined by dividing the desired future trip ends by the trip ends from the first trial. This process can be repeated until these new growth factors approach the value of one and the trip ends balance.

B. Using the Fratar Procedure

The Fratar theory as programed makes the calculations described; however, intrazonal trips are not included. The presence of intrazonal trips in the input trip tables will not affect the program operation. The program can distribute trips for up to 140 zone centroids. The card formats and operating instructions are included in the program description, chapter XX.

C. Data Requirements

Two items of data must be developed as input to the Fratar distribution program and some precautionary measures should be understood. These items are explained below.

1. Trip tables.--The first data which must be developed are the base year trip tables. The trip tables are obtained from the survey cards with the trip table builder program.

2. Growth factors.--The next data to be developed for the Fratar program are the growth factors. Growth factors can be obtained in two ways from trip generation analyses. They can be calculated by dividing the future trip ends from a trip generation analysis by the present trip ends or they may be obtained directly from a generation analysis.

The Fratar program requires that a growth factor (type 21 card) be present for each zone in the trip table and it must be a number greater than zero. These factors are coded in thousandths (XX.XXX).

3. Precautionary measures.--One difficulty in using the Fratar procedure is the inability to obtain a distribution of trips between zones when trips do not presently exist. The Fratar program has a built-in requirement which makes it mandatory to have at least one trip end for each zone in the input trip table.

If there are only a few zones which do not have trip ends, the trip tables could be altered by manually adding one trip end to each origin zone.

If you do not know how many zones have zero trip ends, the survey cards can be processed with the trip end summary program to obtain the information on trip ends for each zone.

D. Program Options

The options in the program consist of the specification of the number of approximations and the trip tables which are to be punched. The number of approximations which have to be made is manually typed into core storage at the beginning of program operation; the number of zones is also typed in at this time. A program switch controls the trip table output. The trip tables may be punched for the last iteration only or they may be punched for each iteration.

E. Checking The Trip Distribution

Before accepting and using the output from the Fratar distribution, the ratio of the desired trip ends to the calculated trip ends must be checked. The output from the Fratar program consists of three types of cards - types 22, 03, and 23. Each type 22 card contains the zone number, the present trip ends, and the future (desired) trip ends. The type 03 cards are the nondirectional trip tables, and the type 23 cards provide the zone number and the calculated future trip ends.

The following criteria are generally used in checking the ratios between desired and calculated trip ends: Most ratios should fall in the range of 0.99 to 1.01. A small number of ratios may be in the range of 0.95 to 1.05. Any exception to the second criterion should be for zones with very few trip ends.

Examples of the data obtained from type 22 and 23 cards are shown in table IX-1. The ratios for these zones are also shown in table IX-1. These ratios must be manually calculated. The ratio for zone 8 in table IX-1 is an instance where the ratio of 1.70 is unimportant.

After the appropriate number of iterations has been made and the ratios are within the acceptable limits, the Fratar trip tables for the final iteration are added to the future gravity model internal trip tables for assignment to the future network.

Table IX-1.--Zonal data and ratios from the Fratar program, fourth iteration

Zone Number	Present Trip Ends	Desired Future Trip Ends	Fratar Trip Ends	Calculated Ratios
1	733	976	977	1.001
2	298	355	358	1.008
3	762	1295	1298	1.002
4	375	277	279	1.007
5	339	360	355	0.986
6	272	305	308	1.010
7	298	399	395	0.990
8	1	10	17	1.700
9	220	308	306	0.994
10	394	743	744	1.001
11	158	444	442	0.995
12	423	639	641	1.003
13	160	293	294	1.003
14	360	665	668	1.005

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CHAPTER X - ANALYSIS OF PROPOSED SYSTEMS AND ASSIGNMENTS	September 1965

A. Assignment of Future Traffic to Proposed Systems

The gravity model trips and through trips must be summed to obtain the trip table for assignment. By using the add trip tables program, the summed trip table can be obtained. This total trip table is now assigned to the proposed system or systems with the assignment 2 program using either an all-or-nothing or a diversion assignment.

B. Analysis of Systems

A well-designed transportation plan should consider each of the following: 1) Is it economically feasible? 2) Does it adequately provide for future travel with an acceptable level of service? 3) Will it effectively serve the projected land uses? 4) Does it utilize an integrated network of all modes of travel? and 5) Will it be compatible with the requirements of the ultimate development of the region?

The analysis of alternate transportation systems and the determination of the best plan is, even with the latest techniques, a trial and adjustment procedure. To date, there is no procedure which will test and analyze the future trip making potential of the study area and automatically prescribe the best possible transportation system. Given a land use plan, a network, and patterns for trip making, the transportation system planner's responsibility is to test the alternate systems and to select the best according to predetermined criteria.

This requires that there must be a set of standards available prior to the development and analysis of a transportation network. These standards should provide information concerning the type of transportation system to be developed, the level of service that the system should provide, its compatibility with community development, and the availability of capital for investment. The type of transportation system with its mixture of highways and transit or other modes of travel, should be established in relation to the estimated person and vehicle travel. A desirable quality of travel service for both person and vehicle movements will result in standards for speed, safety, and accessibility. Economically, the plan must be one in which the benefits will surpass the cost within an acceptable level of annual investment.

The more traditional approach to the development of an optimum transportation system may be divided into four phases: Testing, Analysis, Evaluation, and Adjustment.

1. Testing.--The development of a future transportation system is achieved by a comparison of alternate plans. Each plan is tested and compared with previous plans. The most desirable features of the plan being tested are incorporated into the next trial plan. For example, the transportation plan for the Washington, D.C., area was developed from four basic alternates--the auto dominant, the express bus, the rail transit dominant, and the optimum "balanced" system. Planners for the Philadelphia area are evaluating five basic alternatives in their analysis. A formula based upon construction costs, trip density, and operating costs was utilized in the Chicago area.

Traffic assignment for system planning usually incorporates a "free" assignment to show if a network tends to satisfy travel desires. This can be followed by a series of restrained assignments to attain balance in the traffic loads. In addition, selected trees are plotted for the comparisons of traveltime bands and traffic drainage areas for the sectors of the study area. Assignments also may include an analysis of selected links and the drafting of maps to show the volume to capacity ratios on the selected links. In each traffic assignment, there should be an analysis of the assigned traffic in terms of the estimated total travel cost.

The results of the traffic assignments are posted on the network maps in the desired detail, and the next step would be to confirm the validity of the assignments. The overall travel summary should be evaluated for reasonableness, and spot checks should be made for trip volumes entering and leaving the zones. The amount of checking necessary to verify the validity of traffic assignments varies with the size of the system. When the traffic assignments appear to be valid, the analysis of the assignments is continued.

2. Analysis.--The analysis of traffic assignments in preparation for system design involves a summary of information in various categories. Four possible categories are used in these summations of necessary information.

a. Economic data

Each final system assignment should have the following information specified: Annual travel cost to the motorists, the loss or gain in taxable revenue, construction cost including right-of-way cost, percent change in travel costs from the base year, comparison of total costs per vehicle-mile, and costs of relocation.

The total travel cost to the users of a transportation system has been calculated in past transportation studies using a summary of percent costs, accident costs, and the costs of time.

The construction cost must be estimated for each alternate plan. The precision to which construction costs are estimated must be compatible with the network

being evaluated. If the network has not been described in detail and it is to be considered only a sketch, the construction costs might be calculated by a formula which relates cost per mile to net residential density. Such a procedure was used in Pittsburgh and Chicago. Major structural expenditures should be calculated separately. Right-of-way and other costs should also be estimated for the cost benefit analysis.

b. Performance

The information concerning the trial systems usually includes the following items: The average system speeds by type of facility, the total vehicle-miles and vehicle-hours of travel, the average traveltime and distance by type of facility, and the total miles of network coded for each type of facility.

c. Design

Some of the elements of design which should be included in the analysis of the traffic assignment are: The total system capacity by facility type, comparisons of trip length frequency distributions, total trips assigned to the network, total mileage by volume group, average spacing of freeway interchanges, person-miles per mile of roadway for each facility type, and the volume-capacity ratios for each capacity group and each major link.

d. Other

An analysis of either sketch plans or design plans will also involve the calculation of several other items of information such as the number of displaced persons or families. In addition, the network should be studied for its compatibility with other area improvement programs such as urban renewal, redevelopment projects, utility improvements or extensions, etc. The final plan should be studied with regard to the relationship of the transportation system within the study area to the regional and national transportation networks.

3. Evaluation.--The evaluation of the plan is usually in the form of benefit and cost analysis, an empirical evaluation of the level of service and a measure of the impact on community development. The summation of the travel costs that were developed in the preceding paragraphs, i.e., vehicle operation costs, accident costs, and personal traveltime costs, is compared to the estimated construction cost. This process of traffic assignment and some type benefit and cost analysis are criteria for selecting the best plan or the plan that minimizes the community's total transportation costs. The level of service, which is usually measured with reference to an average speed, is an important measure of the quality of travel service. The volume to capacity ratio is another important parameter in measuring the level of service of a highway system.

4. Adjustments.--For each trial network, the new network is usually developed by simply a modification of the previous network. Adjustments could reflect the following: Decreased freeway spacing, increased freeway capacity, addition of new freeways, improved access to arterial streets, increased arterial street capacity, revised provisions for mass transit and adjusted land use forecasts.

In summary, the evaluation of a transportation network is largely a comparison of alternate schemes. The trial and adjustment process results in the best plan. The best plan should then be subject to detailed analysis for design purposes. This would include such analyses as the close examination of CBD oriented trips, selected link analyses for sections loaded above their capacity, peak-hour studies, and the preparation of illustrations showing the amount of freeway usage, comparison of traveltimes, and volume to capacity ratios. Consideration should also be given to social and community values, the plans and programs of social and land use planners, and other intangible considerations which may be of importance to the general public.

C. Accuracy of Traffic Assignments

The present method for evaluating the adequacy of a traffic assignment is to assign existing trips to a simulated existing network. The accuracy of the assignment may be determined by a link-by-link comparison of the assigned volumes with ground counts. A series of screenlines cutting through the study area may also indicate, to some degree, the accuracy of an assignment. The vehicle-miles of travel for various jurisdictions within a study area may be computed from ground count information and compared to the traffic assignment results.

These comparisons, however, do not measure the differences attributable to the traffic assignment procedures. They may indicate the total error incurred from the following sources: Travel survey, distribution model, ground volume counts, capacity calculations, and the assumptions of the assignment procedures.

Any errors in the traffic assignment procedure may be attributed to excessive zone sizes, faulty link parameters, the assumptions of the minimum path theory, or inability to assign the intrazonal trips.

The only means for minimizing errors are to maintain tight control over the procedures used in the study, to utilize the computer for as many tasks as are feasible, and to check very closely all basic data and all data to be used as input to the computer.

U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

CHAPTER XI - ASSIGNMENT 1 PROGRAM	September 1965

A. IDENTIFICATION

Deck No.: TA 650 - IBM 1620 ASSIGNMENT 1 PROGRAM - Edit, build trees and skim trees

Written by: Mr. William E. Roper, Traffic and Planning Division Mississippi State Highway Department

B. PURPOSE

This program is written to edit the link data, build sample minimum time path trees, punch a link time deck (network description), and build and punch skim trees. The program accommodates a present network and a combination of the present network and a proposed network.

C. EQUIPMENT REQUIREMENTS

This program is written in SPS I for use on a 40K IBM 1620 with card input-output, indirect addressing, branch not last card, branch last card, and automatic divide special features.

D. PROGRAM RESTRICTIONS

This program will accommodate a network which can be described with a maximum of 699 nodes, of which there is no maximum for zone centroids except that the number available is reduced by the number used for the proposed system. The proposed system is limited to a maximum of 140 nodes. The maximum time in a minimum time path is limited to 99.4 minutes and the maximum link time is 9.9 minutes. A maximum of 100 links are allowed in a minimum time path.

E. OPTIONS AND SWITCH SETTINGS

All options are controlled by switch settings except for the range of nodes for which sample or skim trees are desired. These nodes are specified in card type 14. There can be additional type 14 cards in order to specify building individual or groups of test trees. Thus, all desired trees or skim trees do not have to be obtained in one computer run.

Switch Settings	Option
1 - ON and 3 - ON	Skim existing route trees, no card type 02 output.
1 - ON and 3 - OFF	Skim proposed route trees, no card type 02 output.
1 - OFF and 3 - ON	Build sample trees for existing route only. Card type 02 is punched.
1 - OFF and 3 - OFF	Build sample trees for existing and proposed routes. Card type 02 is punched.
2 - ON	Do not compare reversals of links and driving times.
2 - OFF	Compare reversals of links and driving times.
4 - ON	Use zones (centroids) and stations as intermediate nodes.
4 - OFF	Do not use zones (centroids) and stations as intermediate nodes.
PARITY - STOP	
I/O - STOP	
O FLOW - STOP	

F. OPERATING INSTRUCTIONS

1. Press Reset and Insert, then clear storage with check switches to PROGRAM by typing in - 160001000000RS.

2. Press Instant Stop and then Reset after the cycle has been completed.

3. Place the cards in the read hopper in the following order:

   a. Assignment 1 condensed program deck
   b. Card type 11
   c. Card type 12
   d. Card type 14

4. Press LOAD.

5. When machine halts after loading program, press START.

6. When the last card is in the read hopper, press READER START.

7. The end of the computer run is indicated by the type out of "PROCESSING COMPLETE."

8. The output cards are in order by type 17 for each zone punched and then type 02 or by types 17, 18, 19 for each zone punched and then type 02. No sorting is necessary.

G. ERROR MESSAGES AND PROGRAM HALTS

Typed Message	Machine Action	Explanation
"PROCESSING COMPLETE"	Halts.	End-of-Job. To process another system, place a new deck of cards containing card types 11, 12, and 14 in the read hopper. Press START and READER START. Refer to section F - Operating Instructions, step 6.

NOTE: ERROR MESSAGES AND RESTART PROCEDURES

Errors are identified through programed error checks. The message "ER" and "the number representing the error" is typed out. The input area for the last card read (the card causing the error message) is also typed for ER 1 through ER 10, ER 17, and ER 18. For ER 13, 14, and 16, only the data involved are typed. A correction can be typed into the INPUT area (for all except ER's 13, 14, and 16), if feasible, and branching to location 00738 will continue the program. If the error cannot be corrected by typing into the input area, run out the cards in the hopper, correct the cards, load all the data cards back into the read hopper, and branch to the start of the program, location 00402.

Typed Message	Machine Action	Explanation
ER 1	Halts after typing input area.	Incorrect card type, only types 11, 12, and 14 accepted. Correct if feasible, see "NOTE" above or if a blank card, branch to location 00714.
ER 2	Halts after typing input area.	One, but not both, of the nodes in the range of node types is equal to ZERO. See "NOTE" above.
ER 3	Halts after typing input area.	More than 140 proposed street and freeway nodes specified in card type 11, see "NOTE" above.
ER 4	Halts after typing input area.	The low freeway node is not of a higher number than other type nodes and a proposed system is indicated. See "NOTE" above.
ER 5	Halts after typing input area.	City code in input card is not the same as the code in card type 11. This is checked for consistency by all programs. See "NOTE" above.
ER 6	Halts after typing input area.	"A" node is not within the range of nodes. See "NOTE" above.
ER 7	Halts after typing input area.	An extension of an "A" node is not within the range of nodes. See "NOTE" above.

Typed Message	Machine Action	Explanation
ER 8	Halts after typing input area.	The computed time for a link is more than 9.9 minutes. The link referred to is the first one in the type out without a driving time. See "NOTE" above for correction and restart procedures.
ER 9	Halts after typing input area.	Minimum time path being built has developed a time greater than 99.4 minutes. To obtain the portion of the path which has been built, branch to location 06114 (A50).
ER 10	Halts after typing input area.	Table C is full. This table contains the nodes yet to be extended. This is an indication that an error in the system of nodes is allowing looping. See "NOTE" above.
ER 13 or ONE-WAY LINK	Types out a link and a time for which an opposite and equal cannot be found. Continues processing.	Opposite extension or time for the link are not equal. Possibly a one-way link. Computer checks the entire system for this condition without stopping if Program Switch 2 is off. This error indicates the card type 12 which may need correcting. The entire system needs reprocessing unless these are one-way links.
POSSIBLY ER 14	Types out the node for which there is no existing system node for continuing the the tree. Continues processing.	Impossible to build an existing route minimum path tree without having to use two freeway nodes in succession. Correct system and reprocess the deck of type 12 cards.
POSSIBLY ER 16	Types out the node in error. Continues processing .	Indicates there is a node within the specified range of nodes for which there are no extensions.

Typed Message	Machine Action	Explanation
ER 17	Halts after typing the range of nodes from the card type 11.	A node in the range of nodes is greater than 699. The type out is the range of nodes. See "NOTE" above.
ER 18	Halts after typing the card type 11 which is supposed to contain the map scale factor.	No map scale conversion factor in the card type 11, and the link time needs to be computed for a link. See "NOTE" above.

H. TIMING

A 366 node system required 17 minutes for processing and punching three sample trees (card type 17) and the link times (card type 02). There were no errors printed out in this run.

A separate run to obtain skim trees for the same 366 node system required 15 minutes for processing and punching skim trees for 84 zones.

I. METHOD

The program first reads the type 11 card which establishes the table limits. Next, the program reads the type 12 cards and edits them for applicable errors. If program switch 2 is off, each link is compared with its reverse and error 13 is printed for each link which is not equal to its reverse. The type 14 card is then read and the trees are alternately built and punched for each node specified. After punching the last tree, the program checks for another type 14 card. If there are no additional type 14 cards, the type 02 cards (links and times) are punched and the end-of-job message is typed. If there are additional type 14 cards, the specified trees are built and punched and then, the type 02 cards are punched.

The minimum time path trees in this program are calculated using the procedure developed by Edward F. Moore of Bell Telephone Laboratories in 1957. This algorithm finds the shortest path through a maze. In general, this shortest or minimum patn procedure consists of accumulating and saving the minimum time and path from a starting point, generally an origin zone, to an ever increasing number of points surrounding this point until all destinations are reached.

J. INPUT CARD TYPES - Card columns not specified must be blank.

1. Card Type 11 - Parameter Card

Card Columns	Content
1- 2	Card type, "11"
3- 5	City code
15-17	Lowest number in range of zone centroid nodes, should be 001
18-20	Highest number in range of zone centroid nodes
21-23	Lowest number in range of station nodes
24-26	Highest number in range of station nodes
27-29	Lowest number in range of arterial nodes
30-32	Highest number in range of arterial nodes
33-35	Lowest number in range of freeway nodes (when used)
36-38	Highest number in range of freeway nodes (when used)
55-59	Distance (map) scale factor: 1 mile = XX.XXX map inches or 1 mile = 01.000 miles

2. Card Type 12 - Link Data Card

The program checks to see if driving time is specified for each link. If the driving time is specified, the program uses it and continues to the next link whether travel speed and distance are specified or not. If driving time is not specified, it is computed using the travel speed and distance. Therefore, a combination of both cases can be handled in the same type 12 card, if desired. Less than four extensions of a node are handled automatically.

Card Columns	Content
1- 2	Card type, "12"
3- 5	City code
6- 8	"A" Node
9-11	First "B" node
13-14	Travel speed in miles per hour (XX).
18-20	Map inches or ground miles (XX.X).
25-26	Driving time (X.X).
27-29	Second "B" node
31-32	Travel speed in miles per hour (XX).
36-38	Map inches or ground miles (XX.X).
43-44	Driving time (X.X).
45-47	Third "B" node
49-50	Travel speed in miles per hour (XX).
54-56	Map inches or ground miles (XX.X).
61-62	Driving time (X.X).
63-65	Fourth "B" node

Card Columns	Content
67-68	Travel speed in miles per hour (XX).
72-74	Map inches or ground miles (XX.X).
79-80	Driving time (X.X).

3. Card Type 14 - Control Card

There may be more than one card type 14. See E - Options and Switch Settings.

Card Columns	Content
1- 2	Card type, "14"
3- 5	City code
6- 8	Low node number in the range of trees which are to be built and punched. This would be the centroid number when obtaining skim trees.
9-11	High node number in the range of trees which are to be built and punched. If only one tree is to be built and punched, code high node equal to low node. This would be the centroid number when obtaining skim trees.

K. <u>OUTPUT CARD TYPES</u> - Card columns not specified may be zero or blank.

1. Card type 17 - Existing System Trees

Card Columns	Content
1- 2	Card type, "17"
3- 5	City code
6- 8	Home node ("A" node of origin for this tree)
9-11	"B" node of destination
12-14	Back node which forms the link of the path with the "B" node in columns 9-11

Card Columns	Content
18-20	Accumulated driving time to the "B" node in columns 9-11 from the "A" node (XX.X minutes).
27-29	"B" node of destination
30-32	Back node which forms the link of the path with the "B" node in columns 27-29
36-38	Accumulated driving time to the "B" node in columns 27-29 from the "A" node (XX.X minutes).
45-47	"B" node of destination
48-50	Back node which forms the link of the path with the "B" node in columns 45-47
54-56	Accumulated driving time to the "B" node in columns 45-47 from the "A" node (XX.X minutes)
63-65	"B" node of destination
66-68	Back node which forms the link of the path with the "B" node in columns 63-65
72-74	Accumulated driving time to the "B" node node in columns 63-65 from the "A" node (XX.X minutes).

To trace the existing system path from a home node ("A" node) to any destination ("B" node), it is necessary to begin at the destination node and use back nodes to reach the home node. The path is traced backwards.

2. Card Type 18 - Intermediate links between present and proposed system trees

Card Columns	Content
1- 2	Card type, "18"
3- 5	City code
6- 8	Home node ("A" node of origin for this tree)

Card Columns	Content
9-11	"B" node of destination
12-14	Back node which forms the link of the path with the "B" node in columns 9-11
18-20	Accumulated driving time to the "B" node in columns 9-11 from the "A" node (XX.X minutes).
27-29	"B" node of destination
30-32	Back node which forms the link of the path with the "B" node in columns 27-29
36-38	Accumulated driving time to the "B" node in columns 27-29 from the "A" node (XX.X minutes).
45-47	"B" node of destination
48-50	Back node which forms the link of the path with the "B" node in columns 45-47
54-56	Accumulated driving time to the "B" node in columns 45-47 from the "A" node (XX.X minutes).
63-65	"B" node of destination
66-68	Back node which forms the link of the path with the "B" node in columns 63-65
72-74	Accumulated driving time to the "B" node in columns 63-65 from the "A" node (XX.X minutes).

3. Card Type 19 - Proposed System Trees

Card Columns	Content
1- 2	Card type, "19"
3- 5	City code
6- 8	Home node ("A" node of origin for this tree)

Card Columns	Content
9-11	"B" node of destination
12-14	Back node which forms the link of the path with the "B" node in columns 9-11
18-20	Accumulated driving time to the "B" node in columns 9-11 from the "A" node (XX.X minutes).
27-29	"B" node of destination
30-32	Back node which forms the link of the path with the "B" node in columns 27-29
36-38	Accumulated driving time to the "B" node in columns 27-29 from the "A" node (XX.X minutes)
45-47	"B" node of destination
48-50	Back node which forms the link of the path with the "B" node in columns 45-47
54-56	Accumulated driving time to the "B" node in columns 45-47 from the "A" node (XX.X minutes).
63-65	"B" node of destination
66-68	Back node which forms the link of the path with the "B" node in columns 63-65
72-74	Accumulated driving time to the "B" node in columns 63-65 from the "A" node (XX.X minutes).

To trace a proposed system tree, begin at any destination ("B" node) in card type 19 and use back nodes until the one reached is blank. Switch to card type 18 and obtain the back node for this "B" node. Next, go to card type 17 and continue to the home node ("A" node). The path is traced backwards.

4. Card Type 02 - System Link Times, Input to the Assignment 2 Program

Card Columns	Content
1- 2	Card type, "02"
3- 5	City code
6- 8	"A" node
12-14	"B" node (1)
19-20	Link time, X.X minutes
30-32	"B" node (2)
37-38	Link time, X.X minutes
48-50	"B" node (3)
55-56	Link time, X.X minutes
66-68	"B" node (4)
73-74	Link time, X.X minutes

5. Card Type 24 - Skim Trees for Present or combination of Present and Proposed System

Card Columns	Content
1- 2	Card type, "24"
3- 5	City code
6- 8	Blank
9-11	Origin zone
12-14	Low destination zone
15	Blank
16-20	Driving time 1 (Low destination zone)
21-25	" " 2 " " " +1
26-30	" " 3 " " " +2

Card Columns	Content
31-35	Driving time 4 (Low destination zone +3
36-40	" " 5 " " " +4
41-45	" " 6 " " " +5
46-50	" " 7 " " " +6
51-55	" " 8 " " " +7
56-60	" " 9 " " " +8
61-65	" " 10 " " " +9
66-70	" " 11 " " " +10
71-75	" " 12 " " " +11
76-79	Identification (if any)
80	System type: "1" for present system "2" for present and proposed system

L. PROGRAM DESCRIPTION

Prepared in January 1965 by Clyde E. Sweet, Jr., Urban Development Branch, Urban Planning Division, Office of Planning, Bureau of Public Roads.

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

CHAPTER XII - TRIP TABLE BUILDER PROGRAM	September 1965

A. IDENTIFICATION

Deck No.: TA 651 - IBM 1620 TRIP TABLE BUILDER PROGRAM

Written by: Mr. Edwin D. Peterson, Georgia State Highway Department

B. PURPOSE

This program builds trip tables from variable format data card types 02, 03, 04, or 05 and recodes the origin and destination subzones to zones (centroids) which are punched with their associated trip volumes.

C. EQUIPMENT REQUIREMENTS

This program is in SPS II for a 40K IBM 1620 with card input-output, indirect addressing, branch not last card, and automatic divide special features.

D. PROGRAM RESTRICTIONS

A maximum of 1,999 subzones can be recoded to a maximum of 375 zones, with 375 being the highest valid zone number.

The original trip volumes can be rounded to five-position totals from either six-or seven-position totals, depending upon the setting of sense switch 1. The total volume that can be accumulated for any zonal movement is 99,999.

Subzone equivalents (card type 9) should be sorted on the subzone number in ascending order [1/]. There may be numbers missing in either the

1/ Ascending sequence is not mandatory for card type 9 in this program as it is in the Trip End Summary program.

five-digit subzone or the three-digit zone (centroid) sequence, and the three-digit zones may be assigned at random. The three-digit zones (centroids) may be referenced by more than one five-digit subzone number; i.e., the same three-digit number may appear more than once. A trailer card is used with the type 9 cards. A centroid of zero (000) is not allowed. The range of three-digit centroids allowed is 001 through 200.

E. OPTIONS AND SWITCH SETTINGS

Switch Settings	Option
1 - ON	Volume totals are to be rounded from seven positions to five positions
1- OFF	Volume totals are to be rounded from six positions to five positions. Use this switch setting unless there will be totals exceeding six digits.

2, 3, and 4 NOT USED

PARITY - STOP

I/O - STOP

O FLOW - PROGRAM

F. OPERATING INSTRUCTIONS

1. Place all cards in the read hopper in the following sequence:
   a. Object program
   b. Card type 9
   c. Card type 9 trailer card (99999 in subzone field)
   d. Card type 8, format card
   e. Survey card types 02, 03, 04, or 05. Each group must be preceded with a card type 8 describing its format.
2. Clear storage.

3. Press RESET.

4. Press LOAD.

5. When machine halts, press start.

6. End of processing is identified by a typed message.

G. MESSAGES AND PROGRAM HALTS

Typed Message	Machine Action	Explanation
IMPOSSIBLE CARD TYPE	Types out input area (Read + 1) containing error and then halts.	Card type read is not acceptable to this program. Run out cards, correct cards, reload all data and push console start and reader start.
NON-EXISTENT	Types out input area (Read + 1) containing error and then halts.	Card which was read contains a subzone code which is coded 99999 or is nonexistent. Run out card hopper, correct card in error, and reload corrected card and all cards following. Push console start and reader start to continue. If you can't correct the error, pull the job.
EQUIVALENT CODE EXCEEDS 375	Types out message and then halts.	Card which was read contains a zone equivalent which exceeds 375. Run out hopper, correct cards, and reload corrected card and all cards following. Push console start and reader start to continue.
NUMBER OF ORIGINAL SUBZONES EXCEEDS 1999	Writes error message and halts.	There is no restart from this error. Correct type 9 cards and reload program to begin again.
END OF SQUARE TRIP TABLE JOB	Halts.	End-of-Job. To run another job, reload program.

H. TIMING

The time required in a test run to load the program, to read 739 type 9 cards and 226 survey cards and to punch trip tables for 84 zones was 8 minutes.

The time required for processing about 25,000 trip cards with 300 type 9 cards for 100 centroids was 58 minutes.

I. METHOD

The program begins by reading the subzone equivalents (type 9 cards). It then reads a type 8 format card and processes all the following survey data cards by converting the subzone number to the new zone (or centroid) number and inserting the number of trips in the zonal trip table. After reading all of the survey trip cards, the trip table (type 03 cards) is punched with the trips rounded according to the setting of program switch 1. If there is another card type 8 immediately following the previous survey trip cards, the program will process these cards into the same trip table. There can be any number of data cards sets (type 8 plus data cards), as long as the total numbers of trips do not exceed the five-digit maximum.

The program also checks the card type and checks for consistency in city code.

J. INPUT CARD TYPES

1. Card Type 8 - Format Card for Describing each survey trip card type. Card columns should be blank if the information is not used in the card type being described.

Card Columns	Contents (c.c. = card column)
1	Card type, "8"
2- 4	City code, required
5- 7	Number of zones or centroids, required

Card Columns	Contents (c.c. = card column)
8- 9	Survey card type described in this format card, only 02, 03, 04, or 05 accepted (required)
10-11	High order card column of origin subzone number, required
12-13	Low order c.c. of origin subzone number, required
14-15	High order c.c. of destination subzone number, required
16-17	Low order c.c. of destination subzone number, required
18-19	Card column containing trip purpose "from" (not required for trip table builder)
20-21	Card column containing trip purpose "to" (not required for trip table builder)
22-23	High order c.c. of trip expansion factor, required
24-25	Low order c.c. of trip expansion factor, required
26-27	High order c.c. of station operated. This should be coded so that the first number in this field is an actual digit of the station number. One-digit station numbers should be coded with a leading zero if there are also two-digit station numbers.
28-29	Low order c.c. of station operated
30-31	High order c.c. of station of entry or exit
32-33	Low order c.c. of station of entry or exit
34-35	Direction card column. Codes in survey cards will be: "1" for inbound "2" for outbound
36-37	Lowest external sector code. The sector code number has to be the left most digit in the subzone field of the survey cards. A lowest external sector code of one digit is coded with a leading zero (required).

Card Columns	Content
38	Purpose number, required (1,2,3, or 4)
39-80	Blank

2. Card Type 9 - Survey Subzone to Zone (centroid) equivalents

Card Columns	Content
1	Card type, "9"
2- 4	City code
5- 9	Subzone number, 5 digits
10-12	New centroid or zone number, 5 digits
13-80	Blank

3. Card Type 9 Trailer Card

Card Columns	Content
1	Card type, "9"
2- 4	City code
5- 9	99999
10-80	Blank

K. OUTPUT CARD TYPE

1. Card Type 03 - Trip Volumes

Card Columns	Content
1- 2	Card type, "03"
3- 5	City code
6	Purpose
7- 8	Blank
9-11	Origin zone
12-14	Low destination zone

Card Columns	Content
15	Blank
16-20	Volume 1
21-25	" 2
26-30	" 3
31-35	" 4
36-40	" 5
41-45	" 6
46-50	" 7
51-55	" 8
56-60	" 9
61-65	" 10
66-70	" 11
71-75	" 12
76-80	Identification (optional)

L. PROGRAM DESCRIPTION

This description was prepared in January 1965, by the Urban Development Branch, Urban Planning Division, Bureau of Public Roads.

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

CHAPTER XIII - ADD TRIP TABLES PROGRAM	September 1965

A. IDENTIFICATION

Deck No.: TA 652 - IBM 1620 ADD TRIP TABLES

Written by: Mrs. Lamelle B. Hamner, Urban Planning Division, U.S. Bureau of Public Roads

B. PURPOSE

This program is written to add trip tables by purpose to form a total trip table.

C. EQUIPMENT REQUIREMENTS

This program is written in Fortran II for use on a 20K IBM 1620 with card input-output.

D. PROGRAM RESTRICTIONS

The maximum number of zones allowed is 400. The maximum number of trips from any one zone to any other zone is 99,999. Any number of purposes is allowed. A parameter card is necessary. Input data cards (card type 03) must be sorted on columns 9-11 (zone of origin) for a low to high sequence.

E. OPTIONS AND SWITCH SETTINGS

1. This program has two options which are controlled by card columns 11 and 12 of the parameter card.

   a. Option 1-A "1" punch in column 11 indicates that origin zone sequence must be unbroken. A "blank" in column 11 indicates that there may be origin zones missing.

b. Option 2-A "1" punch in card column 12 indicates that the program will not punch zero trip tables for missing origin zones. A "blank" in this column will cause zero trip tables to be punched for missing zones.

2. Switch Settings:

   Program switches 1, 2, 3, and 4 NOT USED

   PARITY - STOP

   I/O - STOP

   O FLOW - PROGRAM

F. OPERATING INSTRUCTIONS

1. Clear storage.

2. Load cards in read hopper in the following order:

   a. Fortran object deck with subroutines

   b. Parameter card

   c. Type "03" cards (output of Trip Table Builder or Gravity Model Programs). Sorted on card columns 9-11.

   d. Trailer card with "99" in columns 1 & 2

3. Press LOAD. After the program is loaded the message "LOAD SUBROUTINES" is typed out.
   Press console START.

4. When the message "ENTER DATA" is typed out, press console START.

5. After the start of program execution, the parameter card is read and checked, also the number of zones to be processed. If either is incorrect, an error message will be typed out, see G-Messages and Program Halts.

6. Type "03" cards are checked for city code, origin zone, destination zone, and sequence. If any card is out of sort or is in error, an error message will be typed out. See G - Messages and Program Halts.

7. Output of the program will be another deck of "03" cards which will contain the total volume of trips from each zone to every other zone. This deck can be differentiated from the input deck by a "1" in column 8.

8. After the type "03" cards are punched the message "PROGRAM COMPLETE" will be typed out and the machine stops.

G. MESSAGES AND PROGRAM HALTS

Typed Message	Machine Action	Explanation
"A 2 IS NOT IN COLUMN 72." Input card is typed. "PAUSE."	Types out the message, types out the parameter card, and then comes to a pause.	The parameter card requires a 2 as identification in column 72. Correct the card, reload all data, and press start to continue.
"NUMBER OF ZONES IS TOO LARGE, MAXIMUM IS 400." Input card is typed. "PAUSE."	Types out the message, types out the parameter card, and then comes to a pause.	The program can accept only 400 zones as input. Correct the parameter card, reload all data, and press start to continue. If more than 400 zones, pull job.
"CARD____IS IN ERROR." Input card is typed. "1 ERROR CARDS - JOB ENDED. STOP."	Types out the message, types out the type 03 card causing the error, types out an additional message, and halts.	Wrong card type - it is not a type 03 or a type 99 card. Correct card, reload the program and begin again.
"CARD OUT OF SORT. CARD____IS IN ERROR." Input card is typed. "1 ERROR CARDS - JOB ENDED. STOP."	Types out the message, types out the card, types out additional message and halts.	Card type 03 is out of sort. Correct the deck and reload the program to begin again.
"CARD____IS IN ERROR." Input card is typed. "1 ERROR CARDS - JOB ENDED. STOP."	Types out the message, types out the card in error, types out additional message and halts.	Low destination zone in type 03 card is in error. Correct the deck and reload the program to begin again.
"PROGRAM COMPLETE, ___CARDS READ, 00 CARDS NOT USED."	Types the message and halts.	Successful run of the program. Reload program to run another job.

NOTE: A blank, ____, in the above error messages signifies that the sequence number of the card which was read will be typed out.

H. TIMING

For a machine with the automatic floating point special feature, it took 10.2 minutes to load the program, add three purpose trip tables and punch the total trip table for 84 zones.

For a machine without the automatic floating point special feature, it took 14.4 minutes to load, add three purpose trip tables and punch the total trip table for 84 zones.

I. METHOD

The program reads the parameter card and checks on the identification and the number of zones. The type 03 cards are read and checked for city code, for origin zone sequence and for low destination zone. When a type 03 card for the next origin zone is read, the summed trip table for the previous origin zone is punched. This procedure continues until the program complete message or an error message is typed.

J. INPUT CARD TYPES

1. Parameter Card

Card Columns	Content
1- 2	Identification of card type to be processed, "03" required.
3- 5	City code
6-10	Blank
11	"1," if option 1 is selected, otherwise blank.
12	"1," if option 2 is selected, otherwise blank.

Card Columns	Content
13-27	Blank
28-30	Number of zones
31-59	Blank
60-62	"000" (required)
63-71	Blank
72	"2," parameter card identification
73-80	Blank

2. Type 03 Cards- Output of Trip Table Builder Program

Card Columns	Content
1- 2	Card type, "03"
3- 5	City code
6	Purpose code
7- 8	Blank
9-11	Origin zone
12-14	Low destination zone
15	Blank
16-20	Volume 1
21-25	" 2
26-30	" 3
31-35	" 4
36-40	" 5
41-45	" 6
46-50	" 7
51-55	" 8

Card Columns	Content
56-60	Volume 9
61-65	" 10
66-70	" 11
71-75	" 12
76-80	Identification (optional)

3. Type 99 Card - Trailer Card

Card Columns	Content
1- 2	"99"
3-80	Blank

K. OUTPUT CARD TYPES

Type 03 Cards - Input to Traffic Assignment Program 2.

Card Columns	Content
1- 2	Card type, "03"
3- 5	City code
6- 7	Blank
8	"1" (identification for summed trip tables)
9-11	Origin zone
12-14	Low destination zone
15	Blank
16-20	Volume 1
21-25	" 2
26-30	" 3
31-35	" 4
36-40	" 5
41-45	" 6

Card Columns	Content
46-50	Volume 7
51-55	" 8
56-60	" 9
61-65	" 10
66-70	" 11
71-75	" 12
76-80	Identification (optional)

L. PROGRAM DESCRIPTION

This description was prepared in January 1965 by Mrs. Lamelle B. Hamner, Urban Development Branch, Urban Planning Division, U.S. Bureau of Public Roads.

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

CHAPTER XIV - ASSIGNMENT 2 PROGRAM	September 1965

A. IDENTIFICATION

Deck No.: TA 653 - IBM 1620 ASSIGNMENT 2 PROGRAM - All-or-nothing or diversion assignment.

Written by: Mr. William E. Roper, Traffic and Planning Division
Mississippi State Highway Department

B. PURPOSE

This program accepts the link time deck from the Assignment 1 program and packed volume cards from the Add Trip Tables, Gravity Model, or Trip Table Builder programs. The Assignment 2 program builds the minimum path trees and accumulates the volumes on the links on the minimum time paths. The program can provide directional and nondirectional volumes on all links and turning volumes for up to 140 freeway node intersections. For a diversion assignment, a summary of the diversion data is also provided.

C. EQUIPMENT REQUIREMENTS

This program is written in SPS I for use on a 60K IBM 1620 with card input-output, indirect addressing, branch not last card, branch last card and automatic divide special features.

D. PROGRAM RESTRICTIONS

This program will accommodate a network with a maximum of 699 nodes, of which there is no maximum for zone centroids except that the number available is reduced by the number used for the proposed system. The proposed system is limited to a maximum of 140 nodes. The maximum time in a

minimum time path is limited to 99.4 minutes and the maximum time on any link is 9.9 minutes. A maximum of 100 links is allowed in a minimum time path and a maximum volume of 199,998 is allowed on each link. The maximum volume restriction is not checked by the program.

E. OPTIONS AND SWITCH SETTINGS

All options are controlled by switch settings except for the range of centroids and nodes which is specified in card type 01 (parameter card).

Switch Setting	Option
1 - ON	Build trees and accumulate volumes for existing routes only.
1 - OFF	Build trees and accumulate volumes for existing and proposed routes.
2 - ON	Use zones (centroids) and stations as intermediate nodes.
2 - OFF	Do not use zones (centroids) and stations as intermediate nodes.
3 - ON	All-or-nothing assignment only. Card types 04, 05, 06, and 07 can be punched.
3 - OFF	Diversion assignment data are punched. The diversion assignment provides card types 04, 05, 06, 07, and 08.
4 - ON	Input volumes are nondirectional such as the gravity model output. Assignment 2 output will also be nondirectional. Card types 04 and 06 will not be punched.
4 - OFF	Input volumes are directional such as trip table builder output. Assignment 2 output will also be directional. Card types 04, 05, 06, and 07 can be punched.
PARITY - STOP	
I/O - STOP	
O FLOW - STOP	

F. OPERATING INSTRUCTIONS

1. Press Reset and Insert, then clear storage with check switches to PROGRAM by typing in - 160001000000 RS.
2. Press Instant Stop and then Reset after cycle has been completed.
3. Place the cards in the read hopper in the following order:
    a. Assignment 2 condensed program deck
    b. Card type 01
    c. Card type 02
    d. Card type 03
4. Press LOAD
5. When machine halts after loading program, press START.
6. When the last card is in the read hopper, press READER START.
7. The end of the computer run is indicated by the type out of "PROCESSING COMPLETE."
8. The output cards, types 04, 05, 06, and 07 (also type 08 for a diversion assignment) are run out of the hopper. Sorting the cards on card column 2 will place the cards in order by type.

G. ERROR MESSAGES AND PROGRAM HALTS

Typed Message	Machine Action	Explanation
PROCESSING COMPLETE	Halts	End-of-Job. To process another system, place a new deck of cards containing card types 01, 02, and 03 in the read hopper. Press START and READER START. Refer to section F - Operating Instructions, Step 6.

NOTE: ERROR MESSAGES AND RESTART PROCEDURES

Errors are identified through programed error checks. The message "ER" and "the number representing the error" is typed out. The input area for the last card read (the card causing the error message) is also typed for each error condition. A correction can be typed into INPUT-79, if feasible, and a branch 00894 will continue the program. If the error cannot be corrected by typing into the input area, run out the cards in the hopper, correct the cards, load all the data cards back into the read hopper, and branch to the start of the program.

Typed Message	Machine Action	Explanation
ER 1	Halts after typing input area	Incorrect card type, only type 01, 02, or 03 accepted. Correct if feasible. See "NOTE" above.
ER 5	Halts after typing input area	City code in input card is different than that on card type 01. Correct the input area, if feasible. See "NOTE" above. The city code is checked for consistencey by all programs.
ER 9	Halts after typing input area	The time for the minimum path being built has exceeded the 99.4 minute maximum. See "NOTE" above.
ER 10	Halts after typing input area	Table C is full, this table contains the nodes yet to be extended. This is an indication that an error in the system of nodes is allowing looping. See "NOTE" above.
ER 11	Halts after typing input area	The existing system minimum path tree contains more than 100 links. This could be a fault in the tree.

Typed Message	Machine Action	Explanation
ER 12	Halts after typing input area	The proposed system minimum path tree contains more than 100 links. This could be a fault in the tree.
ER 15	Halts after typing input area	The origin and/or destination zone in the type 03 volume card is not within the range of nodes specified in card type 1. See "NOTE" above.

H. TIMING

A 366 node system with 84 zones required 45 minutes to build each tree load the trips and punch the output for an all-or-nothing (directional) assignment.

I. METHOD

The program first reads the type 01 and type 02 cards and edits for card type. If an all-or-nothing assignment is indicated, a tree is built for the origin zone specified in the first volume card, and the trips for this origin zone are accumulated. When the change in origin zone occurs, a new tree is built. If the program switches call for a diversion assignment, both types of trees are built and trips are assigned to the freeway minimum time path trees based on the diversion curve percentage. These procedures are repeated until the last trips are assigned. The output for a directional assignment is then punched as type 04, 05, 06, and 07, cards. Type 04 and 06 cards are not punched for a nondirectional assignment. Card types 06 and 07 are punched for freeway node numbers and card type 08 is punched only for a diversion assignment.

J. <u>INPUT CARD TYPES</u> - Card columns not specified may be zero or blank

1. Card Type 01 - Parameter Card

Card Columns	Content
1- 2	Card type, "01"
3- 5	City code
15-17	Lowest number in range of zone centroid nodes. Should be 001.
18-20	Highest number in range of zone centroid nodes.
33-35	Lowest number in range of station nodes
36-38	Highest number in range of station nodes
51-53	Lowest number in range of arterial nodes
54-56	Highest number in range of arterial nodes
69-71	Lowest number in range of freeway nodes (when used)
72-74	Highest number in range of freeway nodes (when used)

2. Card Type 02 - System Link Times

Card Columns	Content
1- 2	Card type, "02"
3- 5	City code
6- 8	"A" node
12-14	"B" node (1)
19-20	Link time, X.X minutes
30-32	"B" node (2)
37-38	Link time, X.X minutes
48-50	"B" node (3)
55-56	Link time, X.X minutes
66-68	"B" node (4)
73-74	Link time, X.X minutes

3. Card Type 03 - Volume Cards

Card Columns	Content
1- 2	Card type, "03"
3- 5	City Code
6	"Purpose" if card type 03 is output of Trip Table Builder.
7	Blank
8	"1" if card type 03 is output of Add Trip Tables program.
9-11	Origin zone
12-14	Low destination zone
15	Blank
16-20	Volume 1 (Low destination zone)
21-25	" 2 " " " +1
26-30	" 3 " " " +2
31-35	" 4 " " " +3
36-40	" 5 " " " +4
41-45	" 6 " " " +5
46-50	" 7 " " " +6
51-55	" 8 " " " +7
56-60	" 9 " " " +8
61-65	" 10 " " " +9
66-70	" 11 " " " +10
71-75	" 12 " " " +11
76-80	Identificatinn (optional)

K. <u>OUTPUT CARD TYPES</u> - Card columns not specified may be zero or blank

1. Card Type 04 - Directional Link Volumes

Card Columns	Content
1- 2	Card type, "04"
3- 5	City code
6- 8	"A" node
12-14	"B" node (1)
15-20	Directional link volume
30-32	"B" node (2)
33-38	Directional link volume
48-50	"B" node (3)
51-56	Directional link volume
66-68	"B" node (4)
69-74	Directional link volume

2. Card Type 05 - Nondirectional Link Volumes

Card Columns	Content
1- 2	Card type, "05"
3-80	Same as card type 04 except that the volumes are nondirectional

3. Card Type 06 - Directional Turn Volumes

These cards are obtained for only those nodes in the freeway node range.

Card Columns	Content
1- 2	Card type, "06"
3- 5	City code
6- 8	"B" node (location of interchange or intersection)

Card Columns	Content
9-11	"A" node (1)
12-14	"C" node (1)
15-20	Directional turn volume
27-29	"A" node (2)
30-32	"C" node (2)
33-38	Directional turn volume
45-47	"A" node (3)
48-50	"C" node (3)
51-56	Directional turn volume
63-65	"A" node (4)
66-68	"C" node (4)
69-74	Directional turn volume

A directional turning movement is identified by a combinationa of "A, B, and C" nodes. The "B" node locates the interchange. The "A" node to the "C" node indicates the direction of the turning movement.

4. Card Type 07 - Nondirectional Turn volumes

These cards are obtained for only those nodes in the freeway node range.

Card Columns	Content
1- 2	Card type, "07"
3-80	Same as card type 06 except that the volumes are nondirectional.

5. Card Type 08 - Diversion Assignment Data

These cards are punched for a diversion assignment only, to check the assignment for reasonableness.

Card Columns	Content
1- 2	Card type, "08"
3- 5	City code
9-11	Origin zone
12-14	Destination zone
15-20	Present volume
27-29	Time to traverse present path
30-32	Time using freeway path
33-38	Present remaining volume
39-44	Present diverted volume
45-47	Time on present path without common link times
48-50	Time using freeway path without common link times
63-65	Back node of intermediate link used for the freeway path
66-68	"B" node of destination of the intermediate link used for the freeway path
72-76	Time ratio of freeway route time to present route time
78-80	Percentage of traffic diverted

L. PROGRAM DESCRIPTION

Prepared in January 1965, by Clyde E. Sweet, Jr., Urban Development Branch, Urban Planning Division, Office of Planning, Bureau of Public Roads.

U.S. DEPARTMENT OF COMMERCE

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TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

CHAPTER XV - UPDATE SKIM TREES PROGRAM	September 1965

A. IDENTIFICATION

Deck No.: TA 654 - IBM 1620 UPDATE SKIM TREES PROGRAM

Written by: Mr. Edwin D. Peterson, Georgia State Highway Department and revised by Mr. Clyde E. Sweet, Jr., Urban Planning Division, U.S. Bureau of Public Roads

B. PURPOSE

This program prepares the updated skim trees. The program combines the intrazonal and interzonal driving times with the terminal times and develops the total traveltime from each zone to all other zones in the study area.

C. EQUIPMENT REQUIREMENTS

This program is written in Fortran II for use on a 20K IBM 1620 with card input-output.

D. PROGRAM RESTRICTIONS

This program will process a maximum of 200 zones.

E. OPTIONS AND SWITCH SETTINGS

1. There are no options, program switches are not used.
2. Switch Settings:

   PARITY - STOP

   I/O - STOP

   O FLOW - PROGRAM

F. OPERATING INSTRUCTIONS

1. The type 31 cards must be in sort by origin zone. The type 24 cards must be in order as punched from the Assignment 1 program - major sort on origin zone and minor sort on low destination zone.

2. Clear storage with switches set to program.

3. Press RESET.

4. Place cards in the read hopper in the following order:

   a. Fortran object deck with subroutines

   b. Parameter card

   c. Type 31 cards

   d. Type 24 cards

5. Press LOAD to begin.

6. The message "LOAD SUBROUTINES" will be typed out. Press START.

7. The message "ENTER DATA" will be typed out. Press START to begin processing.

8. Press READER START for the last type 24 card.

9. Error halts may occur during processing.

10. After all cards are processed and the output is punched, the job complete message will be typed out and the computer will halt.

G. MESSAGES AND PROGRAM HALTS

Typed Message	Machine Action	Explanation
"NUMBER OF ZONES IN ERROR, CORRECT PARAMETER CARD, RELOAD DATA, PRESS START TO BEGIN AGAIN. PAUSE."	Types message and halts.	Check the number of zones used in the parameter card. The maximum permissible is 200. Press start to begin by reading the parameter card again.
"NOT CARD TYPE 31, CORRECT CARD, RELOAD ALL DATA, PRESS START TO BEGIN AGAIN. PAUSE."	Types message and halts.	Check card order, correct card, reload parameter card and all data, press start to begin again.
"NOT CARD TYPE 24, CORRECT CARD, RELOAD TYPE 24 CARDS, CLEAR PUNCH HOPPER, PRESS START TO PROCEED. PAUSE."	Types message and halts.	Correct card, reload type 24 cards, run out and restart the punch, press console start to continue.

Typed Message	Machine Action	Explanation
"JOB COMPLETE. STOP."	Types message and halts.	Successful run. Reload program to make another run.

H. TIMING

To load the program, read the type 31 and 24 data cards, and punch the updated skim trees for 84 zones required 21 minutes.

I. METHOD

The terminal time and intrazonal time for each zone are read in from the deck of type 31 cards which have previously been sorted on the origin zone. This information is stored. The minimum path driving time from each zone to all other zones is read in from the deck of type 24 cards. Halts will occur on certain errors. See G - Messages and Program Halts.

The appropriate terminal times are added to the intrazonal driving time and interzonal driving time to arrive at the total minimum path travel-time for all zone-to-zone movements in the study area.

J. INPUT CARD TYPES

1. Parameter Card

Card Columns	Content
1- 3	Total number of zones (maximum = 200)
4- 6	City code
7- 9	Number of type 24 cards per zone of origin times 12
10-80	Blank

2. Type 31 cards - Terminal and Intrazonal time

Card Columns	Content
1- 2	Card type, "31"
3- 5	City code

Card Columns	Content
6- 8	Origin zone
9-13	Terminal time xxxx.x
14-18	Intrazonal time xxxx.x
19-80	Blank

3. Type 24 cards - Skim Trees for Present or Proposed System

Card Columns	Content
1- 2	Card type, "24"
3- 5	City code
6- 8	Blank
9-11	Origin zone
12-14	Low destination zone
15	Blank
16-20	Driving time 1
21-25	" " 2
26-30	" " 3
31-35	" " 4
36-40	" " 5
41-45	" " 6
46-50	" " 7
51-55	" " 8
56-60	" " 9
61-65	" " 10
66-70	" " 11
71-75	" " 12
76-79	Identification, if any
80	System type "1" = present "2" = present and proposed

K. OUTPUT CARD TYPE

Type 24 cards - Updated Skim Trees for Present or Proposed System

Card Columns	Content
1- 2	Card type, "24"
3- 5	City code
6- 7	Blank
8	"1" - Identification for updated skim trees
9-11	Origin zone
12-14	Low destination zone
15	Blank
16-20	Traveltime 1
21-25	" " 2
26-30	" " 3
31-35	" " 4
36-40	" " 5
41-45	" " 6
46-50	" " 7
51-55	" " 8
56-60	" " 9
61-65	" " 10
66-70	" " 11
71-75	" " 12
76-79	Identification, if any
80	System type "1" = Present "2" = Present and Proposed

L. PROGRAM DESCRIPTION

This description was prepared in January 1965, by the Urban Development Branch, Urban Planning Division, U.S. Bureau of Public Roads.

U.S. DEPARTMENT OF COMMERCE

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TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

CHAPTER XVI - TRIP LENGTH FREQUENCY PROGRAM	September 1965

A. IDENTIFICATION

Deck No.: TA 655 - IBM 1620 TRIP LENGTH FREQUENCY PROGRAM

Written by: Mr. Edwin D. Peterson, Georgia State Highway Department

B. PURPOSE

This program computes and punches the following for each one-minute increment of traveltime: The trip volume, the percentage that the trip volume is of the total volume, and the minutes of travel.

C. EQUIPMENT REQUIREMENTS

This program is written in SPS II for use on a 20K IBM 1620 with card input-output, indirect addressing, branch last card, and automatic divide special features.

D. PROGRAM RESTRICTIONS

This program can accept trip volumes for a maximum of 400 centroids (zones). Trip volumes can be accumulated for each one-minute increment from 1 to 99 minutes of traveltime. The maximum accumulated volume is 999,999.

E. OPTIONS AND SWITCH SETTINGS

1. There are no options; program switches are not used.
2. Switches:

   PARITY - STOP

   I/O - STOP

   O FLOW - PROGRAM

F. OPERATING INSTRUCTIONS

1. Place updated skim trees, type 24 cards, in front of type 03 cards and sort on origin zone (c.c. 9-11).

2. Place the cards in the read hopper in the following sequence:

   a. Condensed program deck

   b. Cards sorted as in step 1.

3. Clear storage.

4. Press RESET.

5. Press LOAD.

6. When machine halts press CONSOLE START.

7. When last card is in read hopper press READER START.

8. End of processing is identified by an "END OF JOB" type out.

G. MESSAGES AND PROGRAM HALTS

Typed Message	Machine Action	Explanation
"IMPOSSIBLE INPUT CARD TYPE."	Types message and halts.	The card read was not a type 24 or a type 03. Correct cards, reload all data, press start to begin again.
"VOLUME CARDS MISSING FOR CENTROID" Origin zone (centroid no.) is typed out.	Types message and centroid number, then halts.	Volume cards are missing for this zone. If this is all right, press start. If this condition is incorrect, correct the input data, reload the program and begin again.
"DRIVING TIME EXCEEDS 99 MINUTES." Types an additional 16 digits.	Types message, types 16 digits, and halts.	There is a time in a type 24 card which exceeds 99 minutes. The digits typed are the last digit of the city code, three zeros, the origin zone, the low destination zone, a zero, and the time. This is a nonrecoverable halt. Check out the skim trees and run the job over.
"END OF JOB"	Types message, and halts.	End-of-job. To run another job, reload the program.

H. TIMING

The time required for loading the program, reading all data cards for 84 zones, and punching the output for 22 minutes of traveltime was 6 minutes.

I. METHOD

The program reads the updated skim trees for one origin zone and sets up a table of time increments for the skim tree times rounded to the nearest whole minute. The trips for this origin zone (centroid) are then read and summed under the appropriate time increments. These procedures are repeated for all origin zones. The percentage of total trips and the minutes of travel are calculated for each time increment. After the final calculation, the type 37 card is punched for each one-minute time increment.

J. INPUT CARD TYPES

1. Card type 24 - Updated Skim Trees for Present or Present and Proposed System

Card Columns	Content
1- 2	Card type, "24"
3- 5	City code
6- 7	Blank
8	"1" Identification punch
9-11	Origin zone
12-14	Low destination zone
15	Blank
16-20	Driving time 1
21-25	" " 2
26-30	" " 3
31-35	" " 4
36-40	" " 5

Card Columns	Content
41-45	Driving time 6
46-50	" " 7
51-55	" " 8
56-60	" " 9
61-65	" " 10
66-70	" " 11
71-75	" " 12
76-79	Identification, if any
80	System type "1" = Present "2" = Present and proposed

2. Card type 03 - Trip Volumes

Card Columns	Content
1- 2	Card type, "03"
3- 5	City code
6	Purpose
7- 8	Blank
9-11	Origin zone
12-14	Low destination zone
15	Blank
16-20	Volume 1
21-25	" 2
26-30	" 3
31-35	" 4
36-40	" 5
41-45	" 6

Card Columns	Content
46-50	Volume 7
51-55	" 8
56-60	" 9
61-65	" 10
66-70	" 11
71-75	" 12
76-80	Identification (optional)

K. OUTPUT CARD TYPE

Card type 37 - Trip Length Frequency

Card Columns	Content
1- 2	Card type, "37"
3- 5	City code
6	Blank
7- 8	Time increment in minutes
9-14	Number of trips
15-19	Percent of total, xxx.xx
20-29	Minutes of travel
30-80	Blank

L. PROGRAM DESCRIPTION

This description was prepared in February 1965, by the Urban Development Branch, Urban Planning Division, Bureau of Public Roads.

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

CHAPTER XVII - TRIP END SUMMARY PROGRAM	September 1965

A. IDENTIFICATION

Deck No.: TA 656 - IBM 1620 TRIP END SUMMARY PROGRAM

Written by: Mr. Don Winter, Georgia State Highway Department

B. PURPOSE

This program recodes five-digit origin and destination subzone codes into corresponding three-digit zone or centroid codes and computes the interzonal trips produced and attracted, intrazonal trips, total productions, total attractions and total trip ends for each production zone or centroid for all three trip purposes as well as for total trips.

C. EQUIPMENT REQUIREMENTS

This program is written in SPS II for use on a 40K IBM 1620 with card input-output, indirect addressing, and automatic divide special features.

D. PROGRAM RESTRICTIONS

This program is not relocatable. It will process cards containing a maximum of 1,000 five-digit subzone codes and recode them into a maximum of 200 zones or centroids. The total accumulated trip volume for any zone or centroid is 99,999.

Subzone equivalents (card type 9) must be sorted on the subzone number in ascending order. There may be numbers missing in either the five-digit subzone or three-digit zone (centroid) sequence, and the three-digit zones may be assigned at random. Three-digit zones may be referenced by more

than one five-digit subzone number; i.e., the same three-digit number may appear more than once. No trailer card is used. A zone (centroid) of zero (000) is not allowed. The range of three-digit centroids allowed is 001 through 200.

E. OPTIONS AND SWITCH SETTINGS

There are no options in this program.

Switch setting

1, 2, 3, and 4 not used

PARITY - STOP

I/O - STOP

O FLOW - PROGRAM

F. OPERATING INSTRUCTIONS

1. Press RESET and INSERT, then clear storage by typing in 160001000000RS.

2. Press INSTANT STOP and RESET.

3. Place cards in read hopper in the following order:

   a. Condensed program deck

   b. Type 9 cards in ascending order. (DO NOT USE the 99999 trailer card used with the Trip Table Builder).

   c. Type 8 card

   d. Card type 02, 03, 04, or 05. Card groups may be entered in any order but only one type will be processed at a time. The type 8 format card must precede each type of survey card.

   e. A card with a record mark in card column 1 (0, 2, and 8 punches).

4. Push LOAD; when machine halts, push console START.

5. At times the program may appear to be in an endless loop. Without errors the program will process until end-of-job message is typed out, ("CONSUMATION.")

G. MESSAGES AND PROGRAM HALTS

Typed Messages	Machine Action	Explanation
ERR 1	Unrecoverable halt	Invalid card type. Correct cards, reload program and begin again.
ERR 2	Unrecoverable halt	Subzone not shown in card type 9. This is either an error in the survey card or there is a type 9 card missing. Correct error and begin again.
ERR 3	Unrecoverable halt	Card type 9 out of sequence. Resequence type 9 cards and begin again.

H. TIMING

The time required in a test run to load the program, to read 739 type 9 cards and 226 survey cards and to punch the trip end summary cards for 84 zones was 5 minutes.

I. METHOD

The program starts by reading the subzone equivalents (type 9 cards). A type 8 format parameter card is then read and each of the survey cards in this format is read and processed by converting the subzone number to the new zone (centroid) number and determining the zone of production and attraction for each survey card. The purpose of the survey trip card is determined from the purpose "to" and purpose "from." A purpose "to" or "from" of zero places the trips in the home based trip purpose category. Similarly, if both purpose "to" and "from" are nonzero, the trips are

placed in the nonhome based trip purpose category. If the trips are home based, the purpose "to" and "from" are checked for a 1. The trip cards with a 1 are placed in the home based work trip category; all other home based trips would be placed in the other home based (nonwork) trip category. At this point, the number of trips from each survey card is placed in the appropriate production and attraction zone tables.

After all the type 8 cards and the following survey cards have been processed, the type 30 cards are punched for each purpose. The purposes are punched in sequence by production zone number in the following order: 1, 2, 3, and 4 (c.c. 39-40). Purpose 1 is work, purpose 2 is nonwork, purpose 3 is nonhome based, and purpose 4 is the total.

Centroids with zero volumes will have a type 30 card punched; centroids not referenced in type 9 cards (e.g., numbers not used as centroids but falling within the sequence of centroid numbers) will have a card type 30 punched. A card type 30 must be present for each centroid, starting with 001 and going to the highest number, for use with the Gravity Model program.

J. INPUT CARD TYPES

1. Card type 8 - Format Card for describing each Survey Trip Card type. Card columns should be blank if the information is not used in the card type being described.

Card Columns	Content (c.c. = card column)
1	Card type, "8"
2- 4	City code, required.
5- 7	Number of zones or centroids, required.
8- 9	Survey card type described in this format card. Only 02, 03, 04, or 05, accepted.

Card Columns	Content
10-11	High order card column of origin subzone number, required.
12-13	Low order c.c. of origin subzone number, required.
14-15	High order c.c. of destination subzone number, required.
16-17	Low order c.c. of destination subzone number, required.
18-19	Card column containing trip purpose "from" (required).
20-21	Card column containing trip purpose "to" (required).

Note: The purposes "to" and "from" used in this program are as follows:

Code	Purpose
1	Work
2	Business
3	Medical-dental
4	School
5	Social-recreational
6	Change travel mode
7	Eat-meal
8	Shop
9	Serve passenger
0	Home

Card Columns	Content
22-23	High order c.c. of trip expansion factor, required.
24-25	Low order c.c. of trip expansion factor, required.
26-27	High order c.c. of station operated. This should be coded so that the first number in this field is an actual digit of the station number. One-digit station numbers should be coded with a leading zero if there are also two-digit station numbers.
28-29	Low order c.c. of station operated.
30-31	High order c.c. of station of entry or exit.

Card Columns	Content
32-33	Low order c.c. of station of entry or exit.
34-35	Direction card column. Codes in survey cards will be: "1" for inbound "2" for outbound
36-37	Lowest external sector code. The sector code number has to be the left most digit in the subzone field of the survey cards. A lowest external sector of one digit is coded with a leading zero, required.
38	Purpose number, not required.
39-80	Blank

2. Card type 9 - Subzone to Zone (centroid) equivalent cards

Card Columns	Content
1	Card type, "9"
2- 4	City code
5- 9	Subzone number, 5 digits
10-12	New centroid or zone number, 3 digits
13-80	Blank

K. OUTPUT CARD TYPE

1. Card type 30 (One deck punched for each purpose)

Card Columns	Content
1- 2	Card type, "30"
3- 5	City code
6- 8	Zone of production
9-13	Interzonal trips produced

Card Columns	Content
14-18	Interzonal trips attracted
19-23	Intrazonal trips
24-28	Total productions
29-33	Total attractions
34-38	Total trip ends
39-40	Trip purpose - 01, 02, 03, or 04 (04 is total of purpose 01, 02, and 03)
41-80	Blank

L. PROGRAM DESCRIPTION

This description was prepared in February 1965, by the Urban Development Branch, Urban Planning Division, Bureau of Public Roads.

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

CHAPTER XVIII - GRAVITY MODEL PROGRAM	September 1965

A. IDENTIFICATION

Deck No.: TA 657 - IBM 1620 GRAVITY MODEL PROGRAM

Written by: Mr. Don Winter, Georgia State Highway Department

B. PURPOSE

This program distributes trips according to the gravity model formula for one purpose at a time. The program computes the trip volumes, zonal attractions and a trip length frequency distribution.

C. EQUIPMENT REQUIREMENTS

This program is written in SPS II for use on a 20K IBM 1620 with card input-output, indirect addressing and automatic divide special features.

D. PROGRAM RESTRICTIONS

The program can accommodate a maximum of 200 zones and 99 one-minute time increments. Input type 24 cards must be sorted as follows: Major sort on origin zone and minor sort on low destination zone, in ascending order. This is the same order in which they are punched from the Assignment 1 program.

E. OPTIONS AND SWITCH SETTINGS

The punching of the gravity model trip tables is controlled by switch 1.

Switch Settings	Option
1 - OFF	Do not punch gravity model type 03 trip tables
1 - ON	Punch gravity model type 03 trip tables
PARITY - STOP	
I/O - STOP	
O FLOW - STOP	

F. OPERATING INSTRUCTIONS

1. Clear storage with check switches set to PROGRAM.
2. Place cards in read hopper in the following order:
   a. Condensed program deck
   b. Type 08 card (gravity model parameter card)
   c. Type 30 cards (productions and attractions, one purpose only)
   d. Type 31 cards (terminal and intrazonal times)
   e. Type 32 cards (traveltime factors for the same purpose as type 30 cards)
   f. Type 33 cards (if K factors are used, they must be inserted in the type 24 deck immediately before the origin zone to which they apply).
   g. Type 24 cards (must be in sort - major sort origin, minor sort low destination)
   h. Blank card with record mark (0, 2, and 8 punches) in column 1
3. Press LOAD to begin loading program.
4. After loading the machine halts.
5. Check switches and hit console START.
6. An end-of-job message will be typed at the end of a successful run. For explanation of typed messages, see G - Messages and Program Halts.

G. MESSAGES AND PROGRAM HALTS

Typed Message	Machine Action	Explanation
"ER 1"	Types message and halts.	Invalid card type. There is no recovery from this halt. Correct cards and reload the program to begin again.
"CONSUMATION"	Types message and halts.	End-of-Job. To run another purpose, change data cards and reload the program.

H. TIMING

The time required to run the gravity model for 22 time increments and to punch the trip tables for 84 zones is 25 minutes. There were no K factors used in this operation.

I. METHOD

The program initially reads the parameter card (type 08) and sets up the counters and test areas. Next the production and attraction cards (one type 30 for each centroid) for one purpose are read. Before processing finally begins, the intrazonal and terminal time cards are read (type 31) and the traveltime factor cards are read (type 32). The application of the gravity model formula begins by reading the K factor cards (type 33, if any) and then the skim tree cards (type 24) for the first zone. The computations begin with the calculation of the total traveltime. The appropriate traveltime factors, productions, and attractions are then used to calculate the trips from the first production zone to all attraction zones. K factors are also applied at this time to any specified attraction zones. On completion of the calculations for the first production zone, K factors and skim trees are read for the next production zone. The trips for each succeeding production zone are computed in the same manner until all centroids have been processed. After the trips have been calculated for each production zone, the trip tables are punched if the option has been specified. The next output are the model attractions (card type 30a). The attractions are then adjusted and punched into card type 30b. The trip length frequency distribution is punched into type 35 cards. An end-of-job message is typed after the last output card has been

punched. Before making the next run of the gravity model, adjust the traveltime factors and punch the adjusted traveltime factors into a new set of type 32 cards. All data except the type 32 cards would remain the same for each calibration of the gravity model. The type 30b cards may be used as input to a succeeding run of the gravity model program in order to balance the model attractions for the same set of traveltime factors.

J. INPUT CARD TYPES

1. Card Type 08 - Gravity Model Parameter Card

Card Columns	Content
1- 2	Card type, "08"
3- 5	City code
6- 8	Number of centroids
9-80	Blank

2. Card Type 30 - Productions and Attractions, one purpose for each run

Card Columns	Content
1- 2	Card type, "30"
3- 5	City code
6- 8	Zone of production
9-13	Interzonal trips produced
14-18	Interzonal trips attracted
19-23	Intrazonal trips
24-28	Total productions
29-33	Total attractions
34-38	Total trip ends
39-40	Trip purpose
41-80	Blank

3. Card type 31 - Terminal and Intrazonal times

Card Columns	Content
1- 2	Card type, "31"
3- 5	City code
6- 8	Origin zone
9-13	Terminal time XXXX.X
14-18	Intrazonal time XXXX.X
19-80	Blank

4. Card type 32 - Traveltime Factors for the same purpose as card type 30

Card Columns	Content
1- 2	Card type, "32"
3- 5	City code
6- 8	Time in minutes
9-13	Traveltime factors XX.XXX
14-80	Blank

5. Card type 24 - Skim Trees for present or present and proposed system

Card Columns	Content
1- 2	Card type, "24"
3- 5	City code
6- 8	Blank
9-11	Origin zone
12-14	Low destination zone
15	Blank
16-20	Driving time 1
21-25	" " 2
26-30	" " 3

Card Columns	Content
31-35	Driving time 4
36-40	" " 5
41-45	" " 6
46-50	" " 7
51-55	" " 8
56-60	" " 9
61-65	" " 10
66-70	" " 11
71-75	" " 12
76-79	Identification (optional)
80	System type "1" = Present "2" = Present and proposed

6. Card type 33 - K Factors, optional

Card Columns	Content
1- 2	Card type, "3"
3- 5	City code
6-15	Blank
16-18	Attraction zone number
19-22	K factor XXX.X.
23-80	Blank

NOTE: All K factors are considered 001.0 unless each group (group by origin) of type 24 cards is preceded by appropriate card type 33. No origin code is necessary, and only those K-factors other than 001.0 must be represented.

K. OUTPUT CARD TYPES

1. Card type 03 - Trip Cards

Card Columns	Content
1- 2	Card type, "03"
3- 5	City code
6- 8	Blank
9-11	Origin zone
12-14	Low destination zone
15	Blank
16-20	Volume 1
21-25	" 2
26-30	" 3
31-35	" 4
36-40	" 5
41-45	" 6
46-50	" 7
51-55	" 8
56-60	" 9
61-65	" 10
66-70	" 11
71-75	" 12
76-80	Identification (optional)

2. Card type 30a - Gravity Model output only, productions and model attractions

Card Columns	Content
1- 2	Card type, "30"
3- 5	City code
6- 8	Zone of production
9-23	Blank
24-28	Total productions
29-33	Total attractions, unadjusted
34-80	Blank

NOTE: The model (unadjusted) attractions are always punched into the first deck of the card type 30 gravity model output.

3. Card Type 30b - Gravity Model Output only, productions and adjusted attractions

Card Columns	Content
1- 2	Card type, "30"
3- 5	City code
6- 8	Zone of production
9-23	Blank
24-28	Total productions
29-33	Total attractions, adjusted
34-80	Blank

4. Card Type 35 - Trip Length Frequency Distribution

Card Columns	Content
1- 2	Card type, "35"
3- 5	City code
6- 8	Time in minutes

Card Columns	Content
9	Blank
10-14	Number of trips
15-19	Percent of total trips XX.XX
20-21	Blank
22-29	Minutes of travel
30-80	Blank

L. PROGRAM DESCRIPTION

This description was prepared in February 1965, by Clyde E. Sweet, Jr., Urban Development Branch, Urban Planning Division, U.S. Bureau of Public Roads.

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

CHAPTER XIX - TRIP COMPARISON PROGRAM	September 1965

A. IDENTIFICATION

Deck No.: TA 658 - IBM 1620 TRIP COMPARISON PROGRAM

Written by: Mrs. Rose M. Hall, Urban Planning Division, U.S. Bureau of Public Roads

B. PURPOSE

This program compares the assigned gravity model trips with the assigned origin-destination survey trips. The program provides differences between the gravity model link volumes and O-D survey link volumes. A statistical analysis of differences is provided for each volume group.

C. EQUIPMENT REQUIREMENTS

This program is written in Fortran II for use on a 60K IBM 1620 with card input-output, automatic divide, and automatic floating point special features. A different version of this program is available for users without the automatic floating point special feature (hardware).

D. PROGRAM RESTRICTIONS

A maximum of 700 nodes can be processed by this program. The nodes must be consecutively numbered beginning with one. The number of volume and difference groups is limited to 15. These groups must range from low to high.

E. OPTIONS AND SWITCH SETTINGS

Options

1. Option to punch table 1.

If table 1 is desired, it must be specified in the parameter card with a "3" coded in column 3. See J - Input Card Types.

2. Option to punch only the portions of table 2 with frequencies. If this option is not selected, all difference groups will be punched for each volume group, with zeros in the difference groups without entries. This option is specified with a "5" coded in column 5 of the parameter card. See J - Input Card Types.

Switch Settings - program switches not used

PARITY - STOP

I/O - STOP

O FLOW - PROGRAM

F. OPERATING INSTRUCTIONS

1. Clear storage.
2. Press RESET.
3. Load cards in the read hopper in the following order:
    a. Fortran object deck with subroutines
    b. Identification card (required)
    c. Parameter card
    d. Difference group card
    e. Volume group card
    f. Type 05 cards from O-D assignment
    g. Type 99 trailer card
    h. Type 05 cards from G-M assignment
    i. Type 99 trailer card
4. Press LOAD.

5. When the message "LOAD SUBROUTINES" is typed out, press console START.

6. When the message "ENTER DATA" is typed out, press console START.

7. Press punch START.

8. There will be a long hesitation before program execution begins. After the program begins execution, the first three cards are typed out:

   a. Parameter card

   b. Difference group card

   c. Volume group card

   If any of these cards are out of order or incorrectly coded, the appropriate error message is typed out and the machine will pause. See G - Error Messages and Program Halts.

9. The program punches the output for the selected options and writes out the totals and an end-of-job message upon completion of the punching.

G. ERROR MESSAGES AND PROGRAM HALTS

Typed Message	Machine Action	Explanation
"ABOVE CARD IS IN ERROR, INCORRECT IDENTIFICATION OR SEQUENCE. CORRECT CARD, RELOAD DATA, PRESS START TO CONT."	Types out the card, then a message, and then it pauses.	Correct card, reload all data, and press start to continue.
"NOT A NO. 5 CARD. STOP."	Unrecoverable halt.	Pull job. Check the assigned link volumes. All cards in the deck are not type 05 cards. Reload program to run again.
"END OF PRO-GRAM. STOP."	Halt.	Processing is complete. List all output cards to obtain the statistical data. Reload the program to make the next comparisons.

H. TIMING

To load the program and run the comparisons for a 25 node test assignment required 8 minutes.

To load the program and run the comparisons for a 366 node assignment required 22 minutes.

I. METHOD

1. The information for the origin-destination survey is read in from the first deck of type 05 cards and stored. This information includes for each A node the connecting B nodes and the corresponding assigned link volumes.

The second deck of type 05 cards (gravity model data) is read in one card at a time. Each card is checked against the corresponding O-D card for the A node number. Then the first B node number is checked and the difference between the O-D and G-M link volumes for this B node is computed. If option 1 has been specified, the node to node comparison is punched. This card will include A node, B node, O-D volume, G-M volume and the difference.

The difference between the two link volumes is then stored in the proper difference group table for the designated volume group, determined by the O-D link volume. At the same time additions are made to the following tables within the volume group:

a. Frequencies for difference group

b. Sum of differences squared

c. Total O-D link volumes

d. Total G-M link volumes

e. Total of frequencies for volume group

This procedure is executed for each of the B nodes on the card. Then the next G-M type 05 card is read in and the process is repeated, until all G-M type 05 cards have been processed.

2. The second portion of the program consists of computing the statistics for the analysis of differences between the origin-destination survey and gravity model link volumes. The program develops and punches the frequency distribution of the differences by volume group. For each volume group it calculates the following: total frequency, total difference, sum of the squares of the differences, mean difference, root-mean-square error of the differences, percent root-mean-square error, total O-D trips, and total G-M trips. If option 2 has been specified, only the groups with frequencies will be punched, otherwise, all difference groups will be punched for each volume group, with zeros in the difference groups without entries.

J. INPUT CARD TYPES

1. Identification Card

Card Columns	Content
1-80	Can contain anything desired, will be used as identification heading on table 1.

2. Parameter Card

Card Columns	Content
1- 2	Blank
3	"3" for option to punch table 1, otherwise blank.
4	Blank
5	"5" for option to punch only that portion of table 2 with entries, otherwise blank.

Card Columns	Content
6-12	Blank
13-16	Number of nodes in network
17-18	Blank
19-20	Number of difference groups
21-22	Blank
23-24	Number of volume groups
25-79	Blank
80	"2"

3. Difference Group Card - Comparison Program Only

Card Columns	Content		
1- 5	First difference group		
6-10	Second	"	"
11-15	Third	"	"
16-20	Fourth	"	"
21-25	Fifth	"	"
26-30	Sixth	"	"
31-35	Seventh	"	"
36-40	Eighth	"	"
41-45	Ninth	"	"
46-50	Tenth	"	"
51-55	Eleventh	"	"
56-60	Twelth	"	"
61-65	Thirteenth	"	"
66-70	Fourteenth	"	"

Card Columns	Content
71-75	Fifteenth difference group
76-79	Blank
80	"3"

4. Volume Group Card - Comparison Program Only

Card Columns	Content		
1- 5	First volume group		
6-10	Second	"	"
11-15	Third	"	"
16-20	Fourth	"	"
21-25	Fifth	"	"
26-30	Sixth	"	"
31-35	Seventh	"	"
36-40	Eighth	"	"
41-45	Ninth	"	"
46-50	Tenth	"	"
51-55	Eleventh	"	"
56-60	Twelfth	"	"
61-65	Thirteenth	"	"
66-70	Fourteenth	"	"
71-75	Fifteenth	"	"
76-79	Blank		
80	"4"		

5. Card Type 05 - Origin-Destination Nondirectional Link Volumes

Card Columns	Content
1- 2	Card type, "05"
3- 5	City code
6- 8	"A" node
9-11	Blank
12-14	"B" node (1)
15-20	Nondirectional link volume
21-29	Blank
30-32	"B" node (2)
33-38	Nondirectional link volume
39-47	Blank
48-50	"B" node (3)
51-56	Nondirectional link volume
57-65	Blank
66-68	"B" node (4)
69-74	Nondirectional link volume
75-80	Blank

This deck must be followed by a trailer card with "99" in columns 1 & 2.

6. Card Type 05 - Gravity Model Nondirectional Link Volumes

Card Columns	Content

(Same format as for Origin-Destination Nondirectional Link Volumes)

This deck must be followed by a trailer card with "99" in columns 1 & 2.

K. OUTPUT CARD TYPES

The output cards from this program are not used as input to any other program. They must be listed in the same order as punched to obtain printed tables. See chapter VI, tables VI-1 and VI-2, for examples of the printed output.

L. PROGRAM DESCRIPTION

This description was prepared in January 1965 by Mrs. Rose M. Hall, Urban Development Branch, Urban Planning Division, U.S. Bureau of Public Roads.

U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

CHAPTER XX - FRATAR TRIP DISTRIBUTION PROGRAM	September 1965

A. IDENTIFICATION

Deck No.: TA 659 - IBM 1620 FRATAR TRIP DISTRIBUTION PROGRAM

Written by: Original written by Terry J. Puckett, Mississippi State Highway Department. Revised by Alabama State Highway Department, October 1964. Revised by William E. Roper, Mississippi State Highway Department, December 1964. Revised by Clyde E. Sweet, Jr., Bureau of Public Roads, June 1965.

B. PURPOSE

This program utilizes the Fratar trip distribution procedure to obtain trip volumes for a future time period.

C. EQUIPMENT REQUIREMENTS

This program was written in SPS I and revised in SPS II for use on a 60K IBM 1620 with card input-output, automatic divide, and indirect addressing special features. This program is not relocatable.

A different version of the Fratar program is available as deck number TA659X. This program requires the additional special features (instructions) TNS and TNF. This program can process one additional zone. This program is also not relocatable.

Either program may be modified to process a lesser number of zones on a machine of smaller core size. The storage requirements for a particular number of zones can be calculated by the following equation:

Storage Locations - 10,680 + 2.5 (No. of Zones) (No. of zones - 1).

D. PROGRAM RESTRICTIONS

A maximum of 140 zones will be processed by this program. The zones must be consecutively numbered and there may not be a zone number of zero. The maximum nondirectional volume for each zone pair is 99,999. Growth factors must be greater than zero and can not exceed 99.999.

E. OPTIONS AND SWITCH SETTINGS

There is only one option controlled by a switch setting. The remaining options are controlled by typing in from the typewriter (see Operating Instructions) or by changing the program. The machine size requirement may be changed by revising the card identified as page 03, line 040, see also Equipment Requirements.

Switch Settings	Option
1 - ON	Punch the type 03 card trip tables for each approximation.
1 - OFF	Punch the type 03 card trip tables for the last approximation only.
2 - ON	Switch 2 must be on at all times.
3 and 4 - NOT USED	
PARITY - STOP	
I/O - STOP	
O FLOW - STOP	

F. OPERATING INSTRUCTIONS

1. Press Reset and Insert, then clear storage with check switches to PROGRAM by typing in - 160001000000RS.
2. Press Instant Stop and then Reset after the cycle has been completed.

3. Place the cards in the read hopper in the following order:

   a. Fratar condensed program deck
   b. Card type 21
   c. Card type 03

4. Press LOAD.

5. The program will load and then immediately begin operation.

6. After about 30 seconds, the message

   "TYPE IN NUMBER OF APPROXIMATIONS XXXXX

   PRESS RS KEY" will be typed. You must then type the five digit number of approximations (e.g. 00004) and hit the RS key.

7. Another message "TYPE IN NUMBER OF ZONES XXXXX"

   "PRESS RS KEY" will be typed. Type in the five digit number of zones which are in the trip tables (e.g. 00084). Press the RS key and the data cards will be read.

8. The machine will now punch a type 22 card for each zone in the trip table.

9. Zero trip ends will not process correctly. If there are zero trips ends for a zone in the trip table, instructions will be typed out on the typewriter. Follow the instructions to restart the processing.

10. The computer will continue for about 15 minutes after punching all of the type 22 card output. At this time the message "APPROXIMATION NUMBER 00001 COMPLETE" will be typed. If the option is specified, type 03 cards will be punched for this approximation and then the machine will continue. If the option has not been specified, the machine will continue the processing immediately.

11. The processing described in step 10 will continue for each iteration as specified in step 6. Upon typing the message for the final iteration, the type 03 trip cards for that approximation will be punched.

12. After punching the trip cards, the type 23 cards will be punched. Following this, the message "PROCESSING COMPLETE" will signal the completion of the run.

G. ERROR MESSAGES AND PROGRAM HALTS

Typed Message	Machine Action	Explanation
PROCESSING COMPLETE"	Halts.	End-of-Job. To process another set of data, place the required data cards (step 3) in the read hopper. Press reader start and console start and then follow the instructions beginning with step 6.
"NO TRIP ENDS FROM ZONE ____" "TYPE IN PRESENT NO. OF TRIP ENDS XXXXX" "PRESS RS KEY"	Halts.	Type in the present number of trip ends as a five digit number e.g. 00066. Then press the RS key to continue processing.

H. TIMING

An 84 zone problem required 1 hour and 5 minutes to load and punch the trip tables for each approximation.

I. METHOD

The program first reads the type 21 growth factor cards. Then the type 03 trip table cards are read and the present trip ends are computed. The present trip ends are multiplied by the growth factor to obtain the number of desired (future) trip ends. If there are zero trip ends for a zone, a message

is printed out with instructions to follow in restarting the program. As the desired trip ends for a zone are calculated, the type 22 card is punched. After a type 22 card has been punched for each zone, the Fratar formula, the present trip ends and the growth factors are used in obtaining the nondirectional trips between each zone pair.

At this time the program tests for the punch option. If the option has been specified, the trip cards are punched for each approximation. If this were the last approximation, the trip cards would be punched without regard to the sense switch option. After punching the trip cards for an intermediate approximation, new growth factors are computed by dividing the desired future trip ends by the calculated trip ends from the previous approximation. The formula is applied again and a new set of trips between zones is calculated. The punch option is checked and the entire process is repeated until the trip cards for the final approximation are punched. At this time, the type 23 cards are punched and the end-of-job message is typed.

J. INPUT CARD TYPES - Card columns not specified must be blank.

1. Card Type 21 - Growth Factors

Card Columns	Content
1- 2	Card type, "21"
3- 5	City code
9-11	Zone
18-22	Growth factor

2. Card type 03 - Output of Trip Table Builder Program

Card Columns	Content
1- 2	Card type, "03"
3- 5	City code
6	Purpose code
9-11	Origin zone
12-14	Low destination zone
16-20	Volume 1
21-25	Volume 2
26-30	Volume 3
31-35	Volume 4
36-40	Volume 5
41-45	Volume 6
46-50	Volume 7
51-55	Volume 8
56-60	Volume 9
61-65	Volume 10
66-70	Volume 11
71-75	Volume 12
76-80	Identification (optional)

K. OUTPUT CARD TYPES - Card columns not specified may be zero or blank.

1. Card type 22 - Present and Desired Trip ends

Card Columns	Content
1- 2	Card type, "22"

Card Columns	Content
3- 5	City code
9-11	Origin zone
23-28	Present trip ends
40-45	Desired (future) trip ends

2. Card type 03 - Nondirectional Trip Volumes

   Same as input type 03 cards except that the volumes are non-directional.

3. Card type 23 - Calculated (future) trip ends

Card Columns	Content
1- 2	Card type, "23"
3- 5	City code
9-11	Origin zone
40-45	Calculated (future) trip ends

L. PROGRAM DESCRIPTION

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U.S. DEPARTMENT OF COMMERCE

BUREAU OF PUBLIC ROADS

TRAFFIC ASSIGNMENT AND DISTRIBUTION FOR SMALL URBAN AREAS

APPENDIX A - REFERENCES	September 1965

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